Enclosure 3

2022 Westinghouse FPUM Slide Package

(Non-Proprietary)

September 2022

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Cranberry Township, PA 16066

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Westinghouse EnCore® Licensing Plans Fuel Performance Update Meeting

Kallie Metzger, Ph.D.
Accident Tolerant Fuel Technology Manager

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Outline

- Westinghouse **EnCore**® Fuel Program
- **ADOPT**™ Updates
- Coated Cladding Updates
- Technologies to Accelerate Development & Licensing

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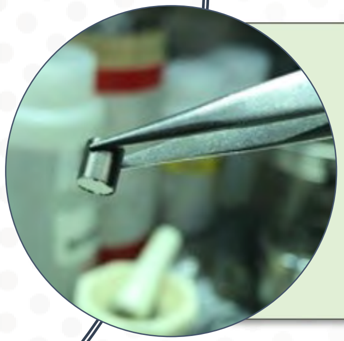
Westinghouse's EnCore® Fuel Program

The EnCore® Fuel program is developing and commercializing advanced fuel products to improve safety and economic performance

Advanced Cladding

- Cr-Coated Zirconium – increases safety and operational margin, and may enable high burnup
- Silicon Carbide Cladding – safety and operational benefits



Advanced Fuel

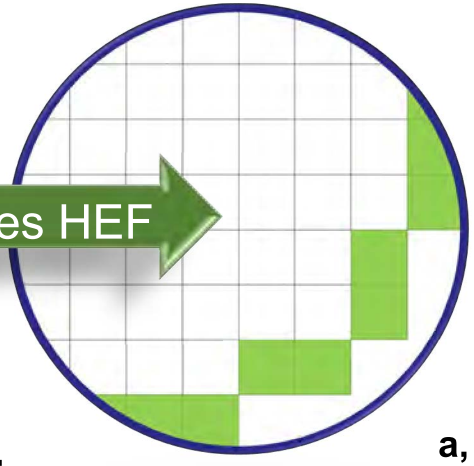
- **ADOPT** fuel pellets – higher density,
- Advanced Pellet (UN) - benefits to fuel cycle costs, and may support high burnup improved fuel cycle economics, thermal properties, and lower operating temperatures

Chromium-Coated Zr Cladding

SiGA® Silicon Carbide (SiC) Composite Cladding

ATF Product Evolution

Enables HEF



ADOPT Pellets

Uranium Nitride (UN) Pellets

$U^{15}N$ Fuel

Photo courtesy of Los Alamos National Lab

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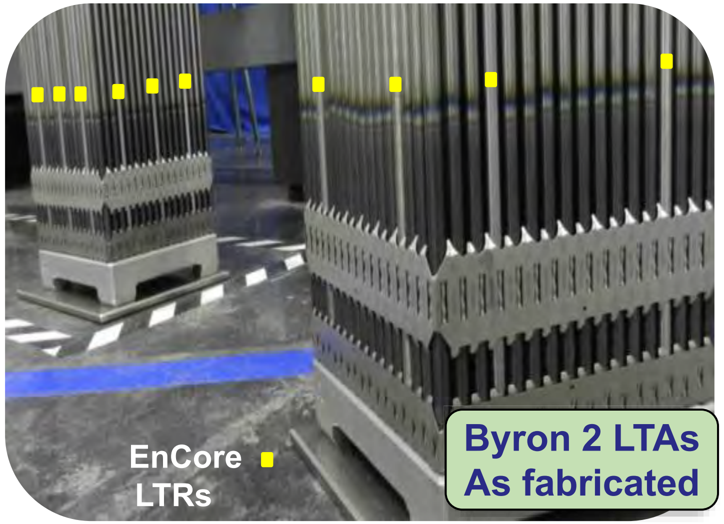
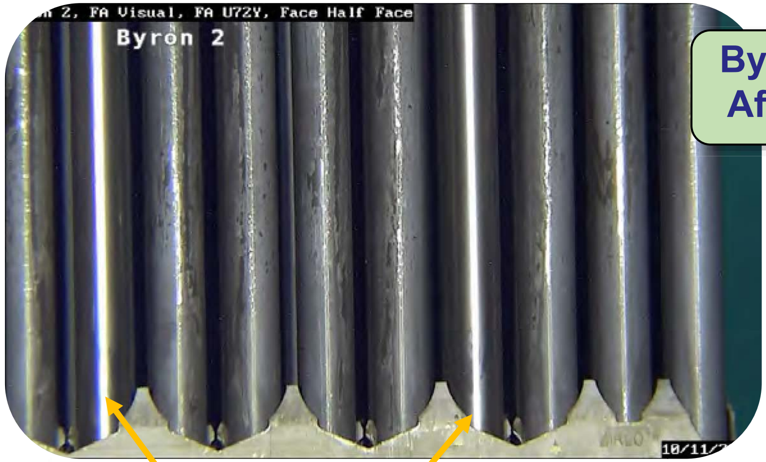
Lead Test Rod & Lead Test Assembly Programs

LTA Campaigns with Utility Partners provide data to support fuel qualification

- Byron 2: inserted Spring 2019
  - Two 17x17 assemblies
  - 16 rods with Cold Spray Cr Coated Cladding
    - 4 rods with **ADOPT** pellets
  - 4 rods with 12" segments of high-density pellets
  - 1st & 2nd cycle Poolside exam show excellent adherence
  - 1st cycle hot cell examination underway at ORNL
- Doel Unit 4: inserted Spring 2020
  - Four 17x17 RFA XL assemblies
  - 32 rods with Cold Spray Cr Coated Cladding with UO_2
- Vogtle Unit 2: Insertion planned for 2023
  - Full assemblies of ATF product (**ADOPT** pellets and coated cladding)
  - 6% ^{235}U rods lead industry in higher enrichment
- EDF: Insertion planned for 2023
  - Lead Test Rods of Cr Coated Cladding
  - This marks the largest R&D program on enhanced fuel that Westinghouse has conducted in Europe
- 3rd cycle Reinsertion in Byron Unit 2:
  - Fuel Assembly, U72Y (**ADOPT** pellets, Pure Cr Coating), Cycle 25
  - Supplies essential high-burnup data for coated cladding, **ADOPT**, and standard fuel licensing





Cr Coated Cladding

Byron 2 LTAs After 1 cycle

- Limited apparent crud accumulation (easily brushed off)
- No significant oxidation
- No deformation
- No apparent wear

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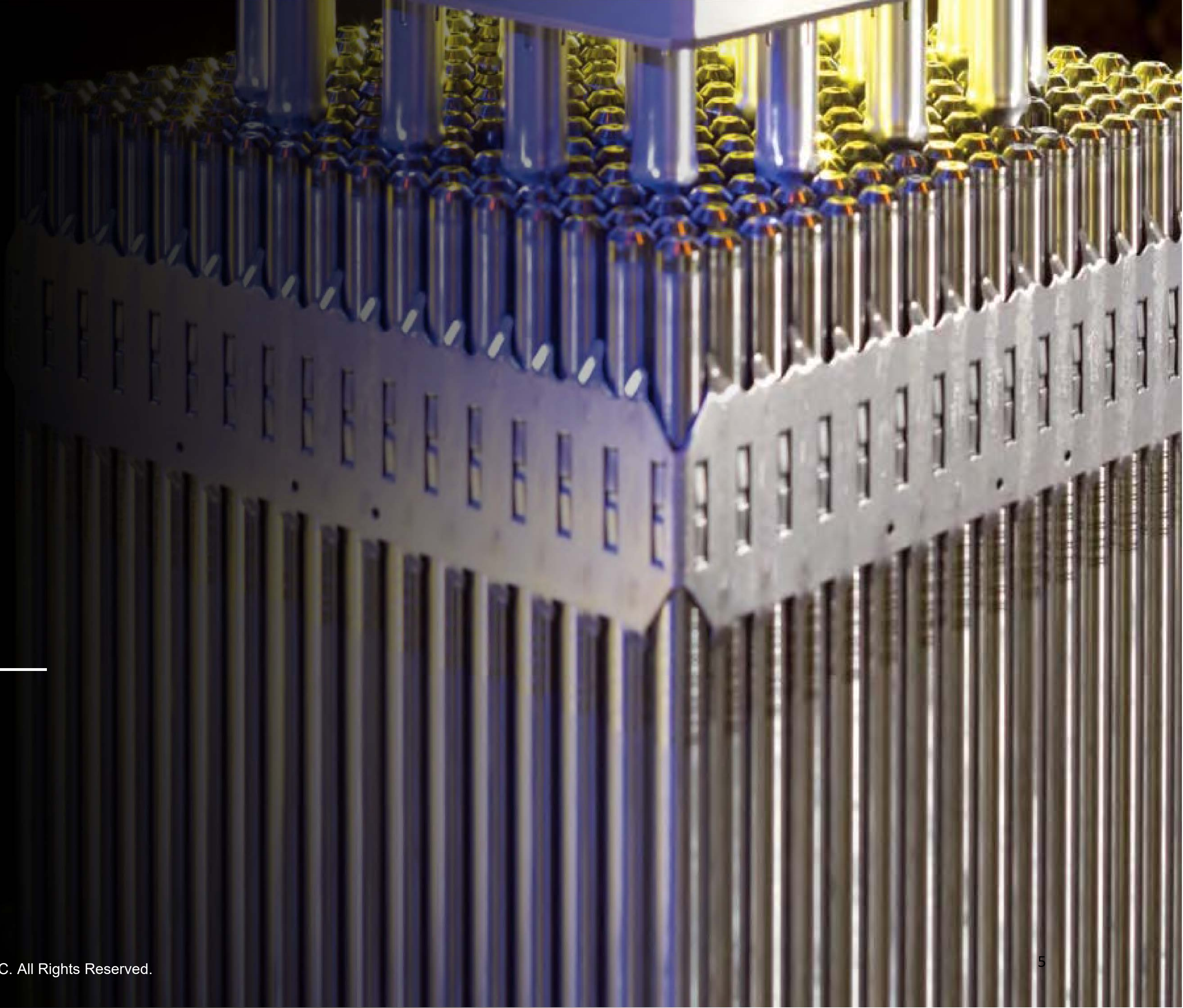
ADOPT WCAP-18482



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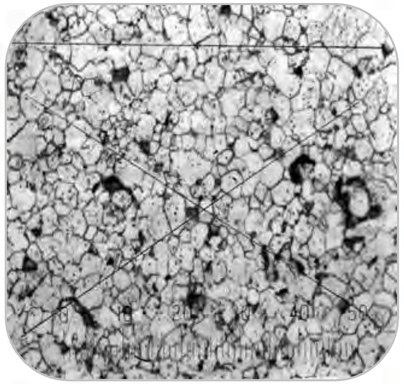
Introduction to ADOPT Fuel

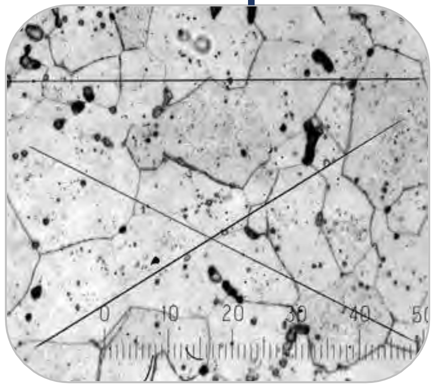
- **ADOPT** (Advanced DOped Pellet Technology) fuel is a standard UO_2 fuel that has been doped with [ ]a,c Cr_2O_3 and [ ]a,c Al_2O_3.

- The additives facilitate densification and diffusion during sintering resulting in a higher density and enlarged grain size compared to undoped UO_2.

Standard pellet



ADOPT pellet



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The ADOPT pellet is characterized by its increased density and larger grain size

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ADOPT Fuel – Submittal Content (WCAP-18482)

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Westinghouse Proprietary Class 2

WCAP-18482-P
Revision 0

May 2020

Westinghouse Advanced Doped Pellet Technology (ADOPT™) Fuel

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ACRS Subcommittee meeting held April 2022

- Concluded with no open items
- ACRS members provided very positive remarks of WEC presenters and the content of the Topical Report
- ACRS elected to forgo a full committee meeting

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Licensing Timeline of ADOPT Fuel

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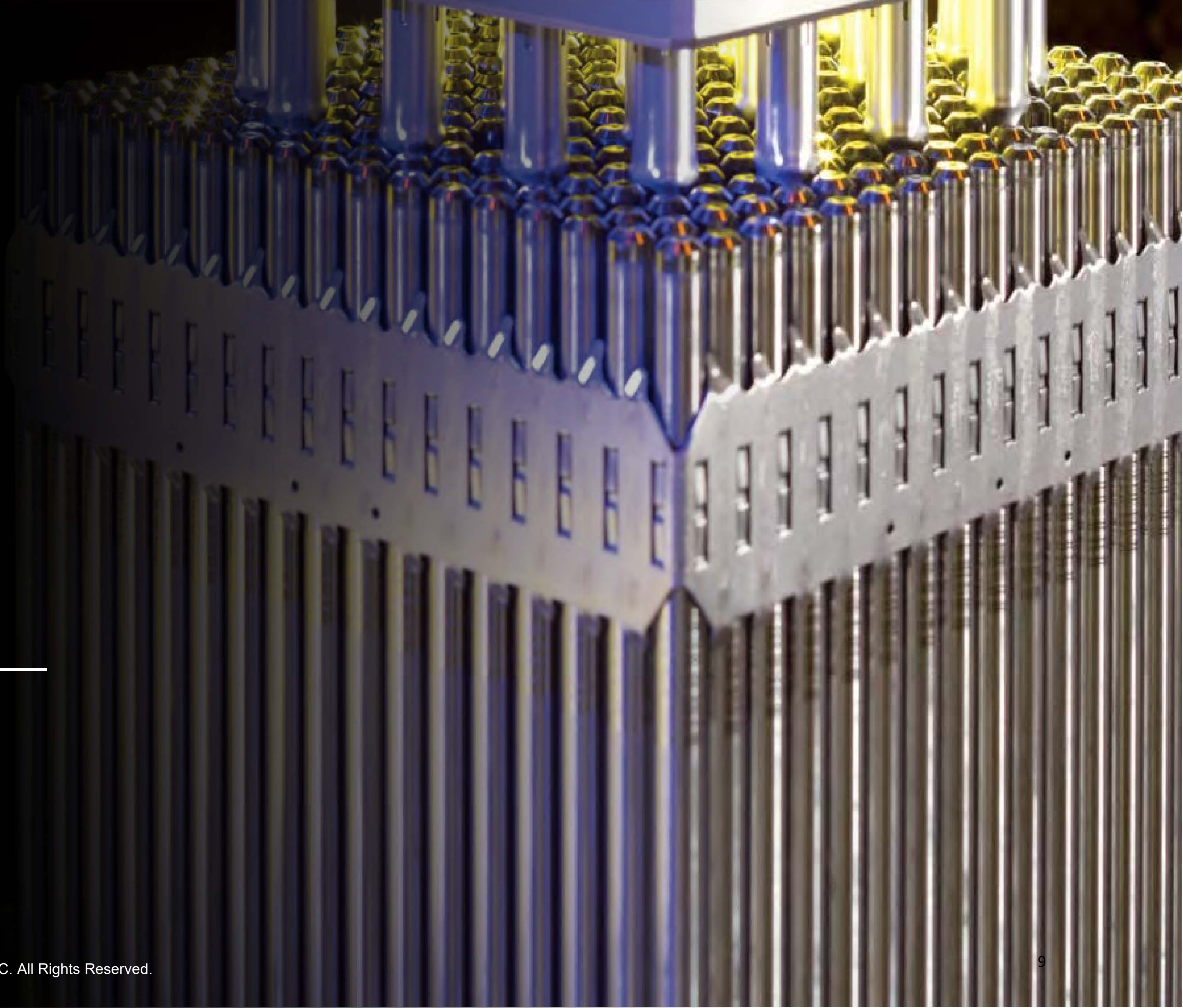
Coated Cladding



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Coated Cladding Process Selection

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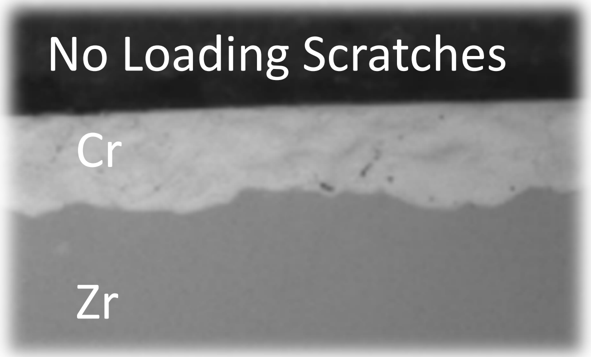
Coated Cladding Process Selection Continued

Engineering Peer Review Highlights

- PVD coatings manufactured using several different technologies showed:
  - “Delicate” behavior, through-coating scratching during rod loading
  - Coating spallation / delamination during tensile and burst tensile tests
  - Decreased fatigue life, crack formation in coating propagating to substrate
  - Suspected columnar grain structure provides corrosion and hydrogen pathway to substrate promoting undercoating corrosion
- Cold spray coatings – robust performance:
  - 2-3X harder than PVD coatings - **eliminates scratching** during rod loading & handling
  - **Excellent adherence to substrate at all strains** - no delamination, even at high burst or tensile failure strains
  - Random grain orientation provides superior toughness, corrosion and oxidation resistance
  - Superior performance to PVD coatings across all performance areas



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ATF and High Burnup (HBu) PIE at ORNL

- 3 ATF rods and 4 HBu rods sent to ORNL hot cells
- Topical Report needs and hot cell resources dictate rod PIE priority

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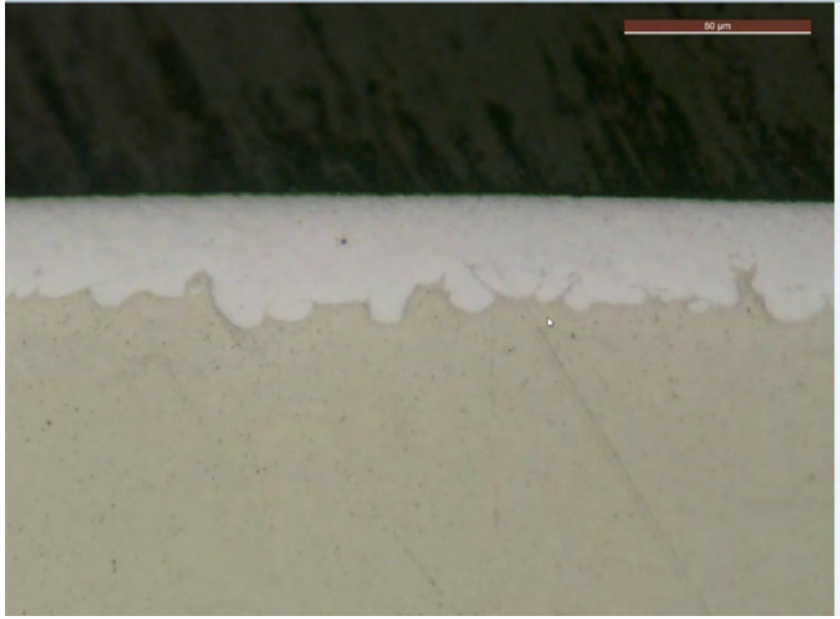
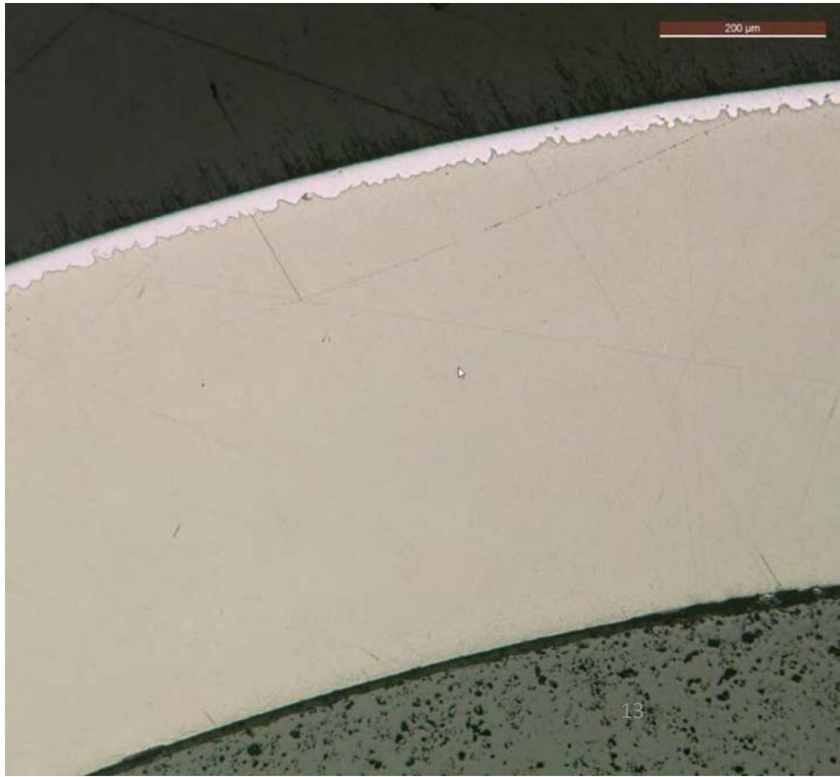
Byron LTRs: Preliminary ORNL PIE Results

- Images of Cr Coated, UO_2 fueled rod at ~30 GWD/MTU
- Region selected for metallography predicted to be peak corrosion/hydrogen containing region for an uncoated rod
- Few apparent hydrides and no cracking observed in what is normally the peak corrosion region
- Complete protection of substrate from Cr Coating:
  - Westinghouse models predict peak oxide thickness and hydride levels of ~0.25 mils and 60 ppm H at the end of fueled region. (Confirmed through ORNL metallography of uncoated region.)
  - Coated cladding metallography in uncoated region, indicates oxide thickness as expected and reduced hydride levels. (~0.22 mils and ~36 ppm H, in the plenum region about 4” above the blanket).
  - Coated cladding metallography 2” in coated region from top, indicates H suppression to ~21 ppm H and no visible Cr oxide





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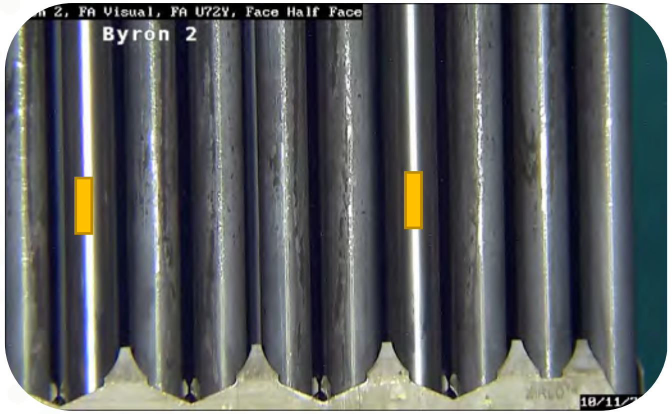
Visual Inspections from LTR Programs Complete

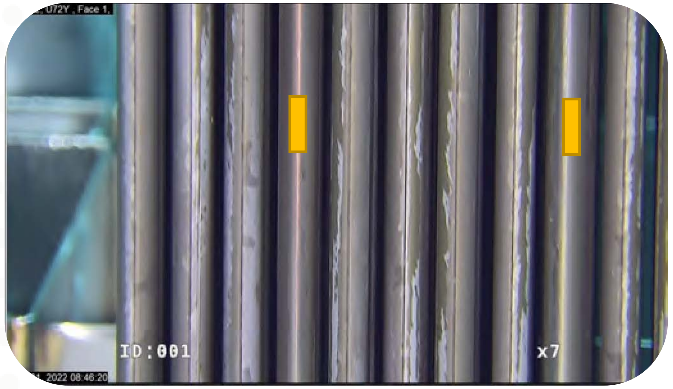
Byron Unit 2 LTRs

EOC 1



Cr Coated Cladding

EOC 2



Doel Unit 4 LTRs

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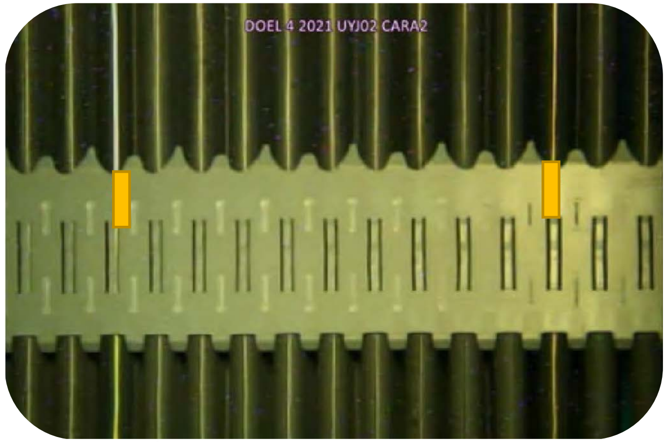

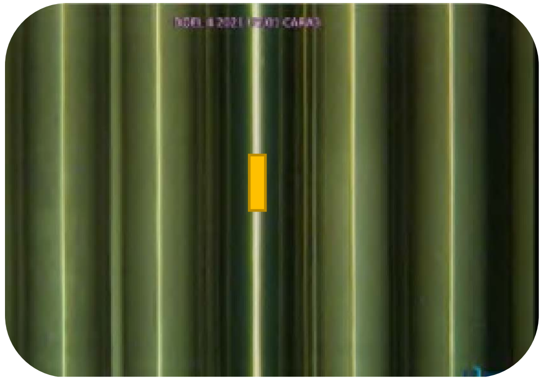

- Byron 1st and 2nd cycle visuals, Doel 1st cycle visuals: Excellent adherence, rods remain shiny with little indication of crud.
- Byon 1st cycle visuals, fiberscope, rod length, profilometry, eddy current complete
- Byron 2nd cycle pool side rod extraction with rod length, fiberscope profilometry, and eddy current scheduled for November. Doel 2nd Cycle poolside exam scheduled Spring 23

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Coated Cladding Qualification Next Steps

- Upcoming ORNL PIE:
  - H+ content analysis Sept 2022 (ORNL)
  - Mechanical testing expected Q4 2022 (ORNL)
- SNC LTA insertion 2023, EDF LTR insertion 2023, Constellation 3rd cycle reinsertion 2023
- Topical Report (TR) Submittal

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Coated Cladding – Submittal Content

Enhancement / benefit	Topical Strategy

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Integrated Licensing Schedule

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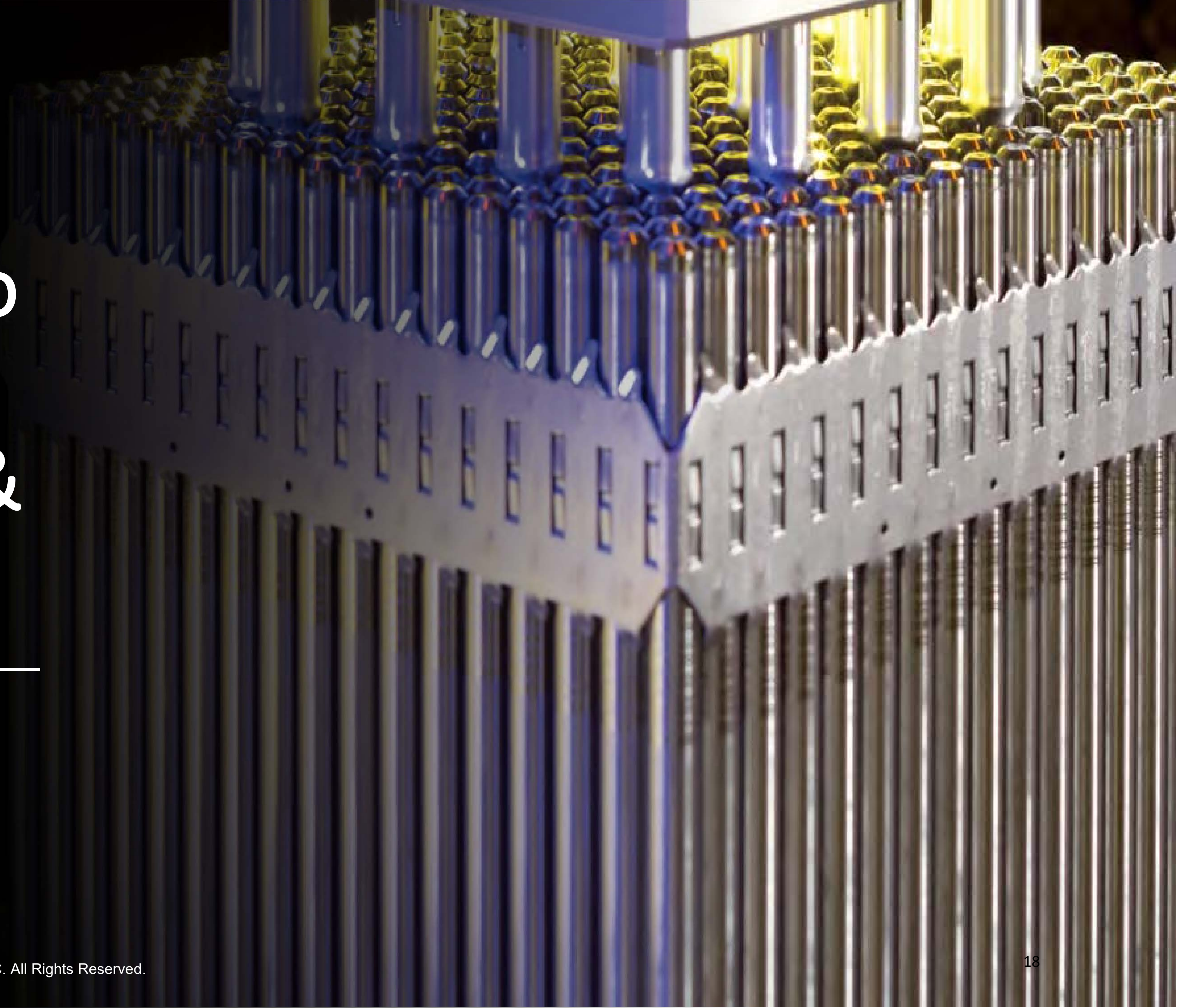
Technologies to Accelerate Development & Licensing



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Advanced Modeling Accelerates Development of New Fuels & Materials

Screening Materials

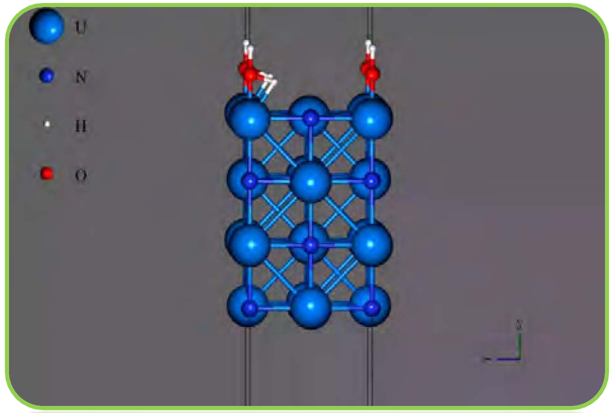
- Predict behavior of materials
- Model materials early in development process

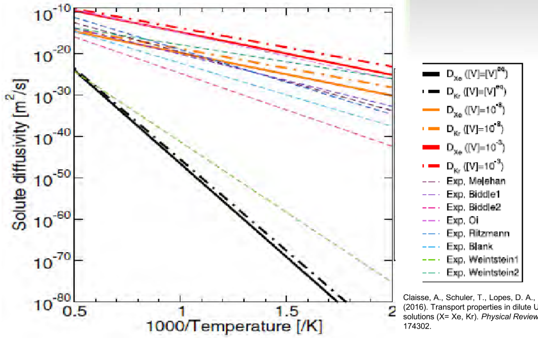
Design of Experiments

- Targeted experiments
- Evaluate behavior in extreme conditions

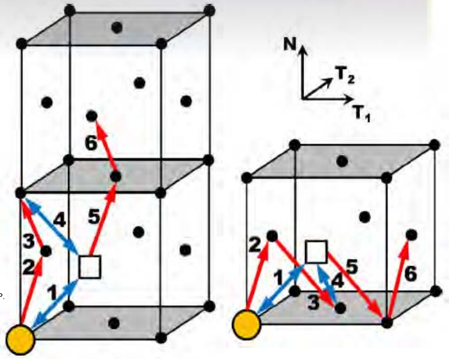
Understanding Experimental Results

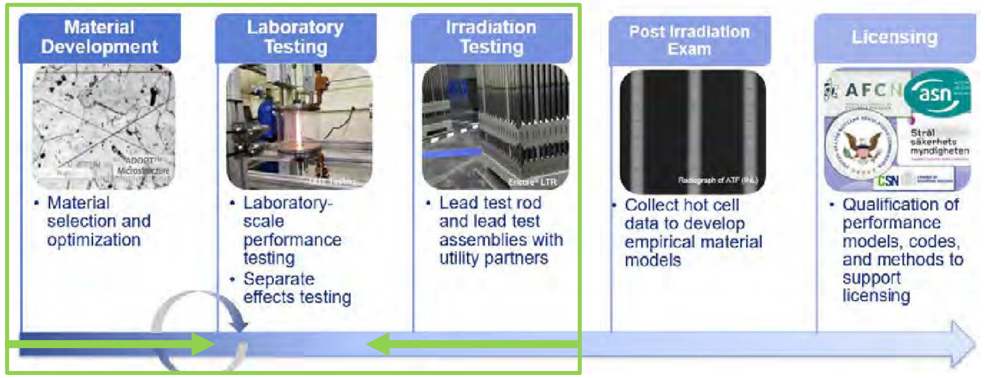
- Interpolation & extrapolation of experimental data
- Draw “smart lines” through limited data sets
- Derive fuel behavior models for licensing codes





Claisse, A., Schuler, T., Lopes, D. A., & Olsson, P. (2016). Transport properties in dilute UN (X) solid solutions (X= Xe, Kr). *Physical Review B*, 94(17), 174302.





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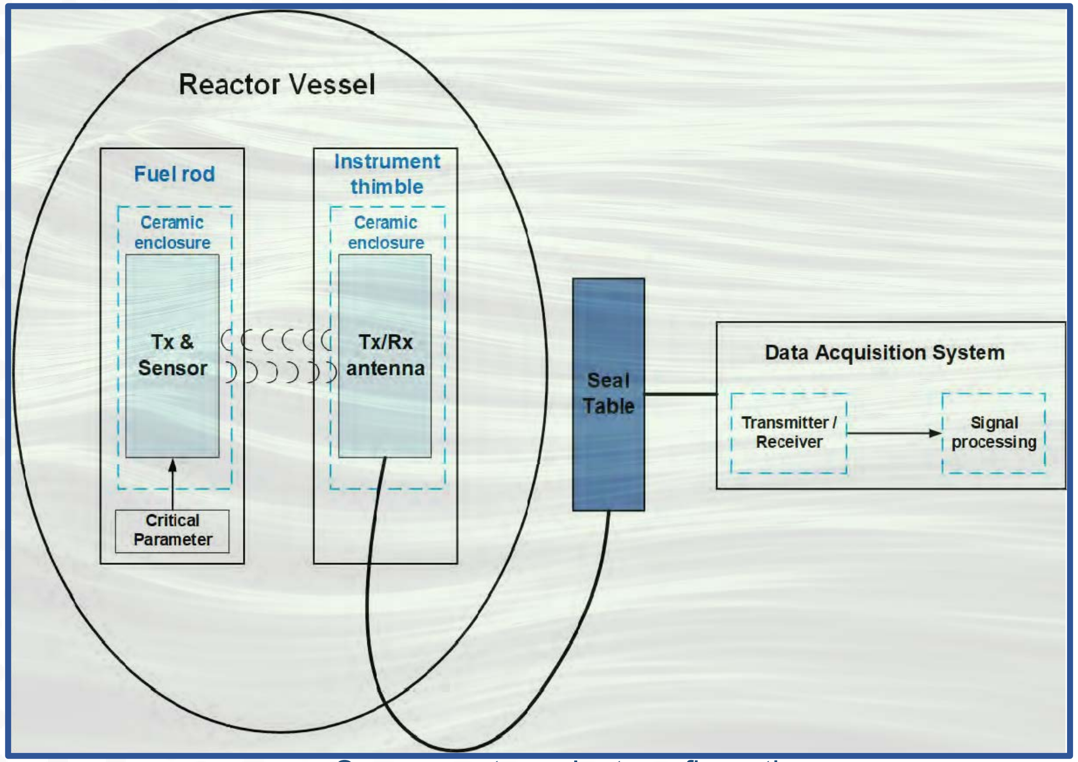
In-Rod Sensor Accelerates Data Collection for Licensing



Sensor system plant configuration

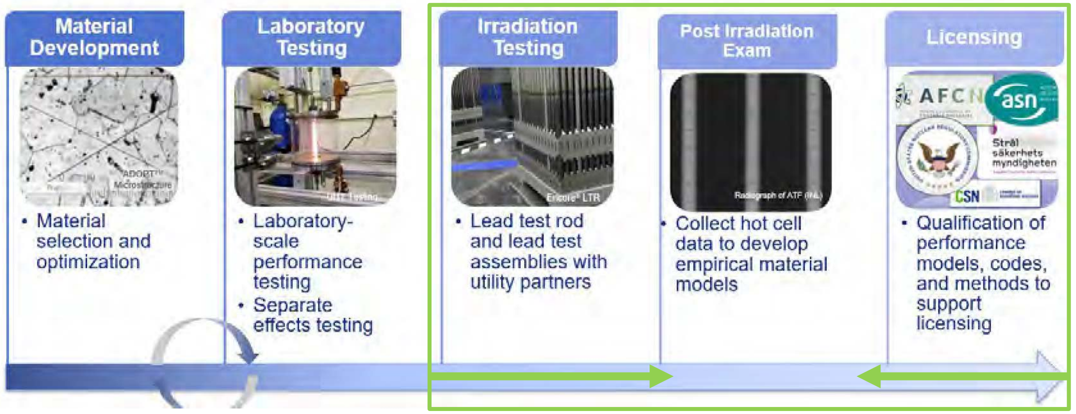

Pressure sensor assembly installed at ORNL HFIR

System Configuration

- Zero penetration, in fuel rod
- Signal wirelessly coupled to transceiver in thimble tube
- Real-time transmission of critical parameters

Benefits

- Real-time data instead of typical "cook and look"
- Increases reliability of models in licensing decisions
- Improvement in power distribution measurement uncertainty



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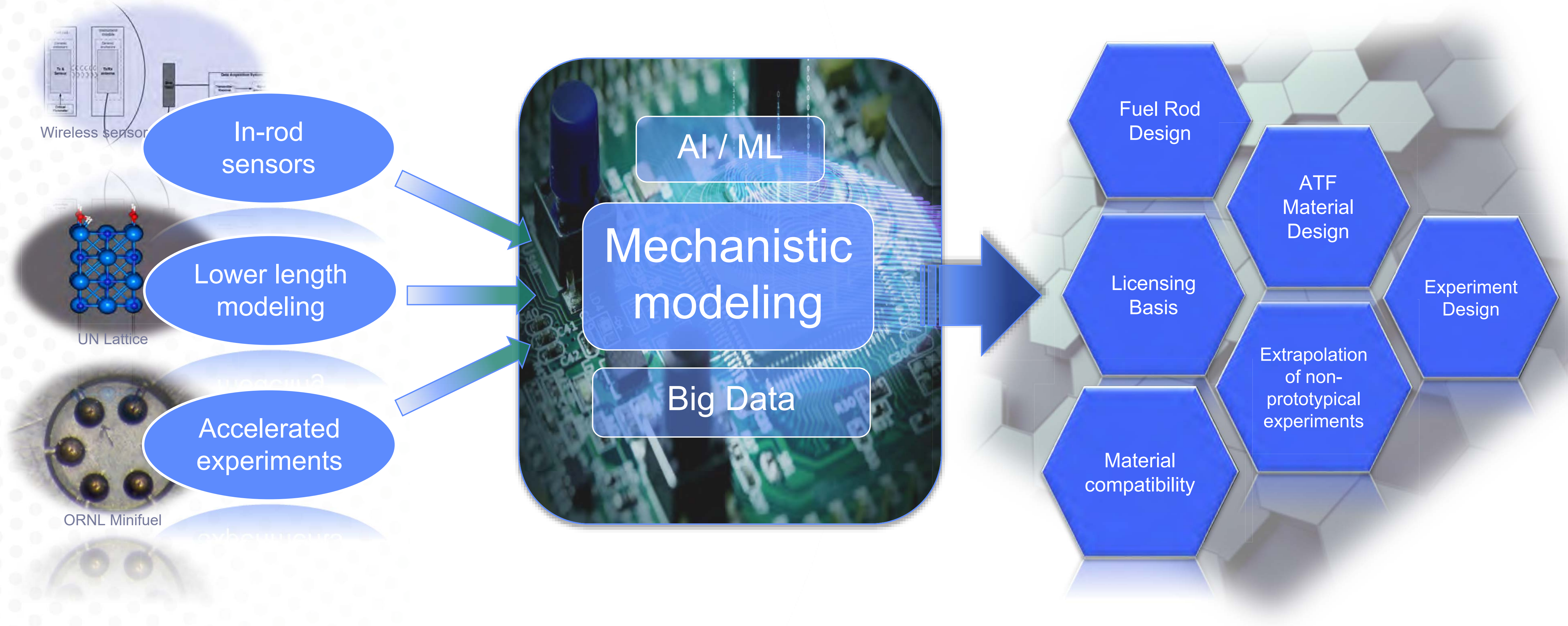
Accelerated Fuel Material Development & Qualification Process



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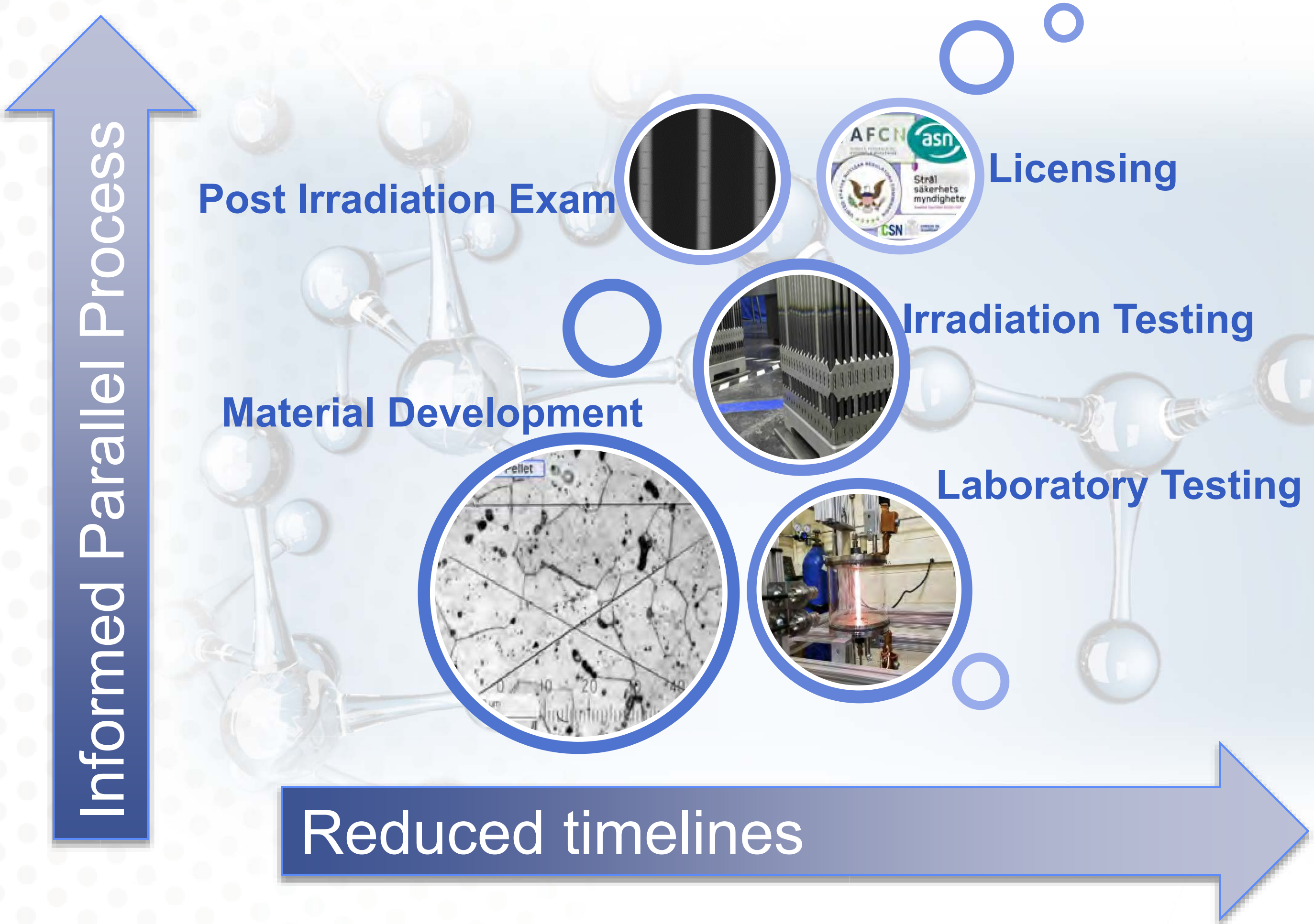
Accelerated Fuel Material Development & Qualification Process



Key Outcomes

- Informed development and model validation run in parallel rather than sequentially
- Reduction in development time
- Condensed licensing timelines
- Accelerates deployment of ATF and advanced technologies

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Questions?

High Energy Fuel
Fuel Performance Update Meeting

Cenk Güler
High Energy Fuel Technology Manager

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HEF Program – Background

- Increased interest in improved fuel cycle economics, 24-month fuel cycles, and energy output beyond 62 GWD/MTU are driving the High Energy Fuel (HEF) Program at Westinghouse
  - It should provide some margin to support power uprates too

- HEF Program goals:
  - Develop codes and methods, analysis, design, licensing and manufacturing associated with the insertion of LTAs with >5 w/o fuel rods into a U.S customer reactor core
  - Develop capability to manufacture a region quantity of >5 w/o for a reload of a U.S. customer core (seeking higher burnup)

- Base material topical reports (ADOPT™, AXIOM®) are expected to be NRC approved prior to the submittal of topical reports associated with HEF

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HEF Program – Topical Report Submittals

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Overall High Energy Fuel Roadmap

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Summary

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DNB Predictive Modeling Using ML Technology

Emre Tatli
Principal Engineer

Westinghouse Fuel Performance Update Meeting

September 2022

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Westinghouse **VISION & VALUES**

together

we advance technology & services to power a clean, carbon-free future.

Customer Focus & Innovation

Speed & Passion to Win

Teamwork & Accountability

Safety • Quality • Integrity • Trust

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Outline

- Background
- Departure from Nucleate Boiling (DNB) Correlation Development Process
- Machine Learning (ML) Technology Overview
- Machine Learning Model Development
  - ML-Based DNB Correlation Inputs
  - Model Architecture
  - Hyperparameter Tuning
  - Dropout Layers
- ML-Based DNB Correlation Evaluation
- ML-Based DNB Correlation Application Process
- ML Model & Result Update
  - Sensitivity Checks
- Summary

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Background

- DNB also referred to as Critical Heat Flux (CHF)

- [ ]a,c
  - Resolution of NSAL-14-5, "Lower Than Expected Critical Heat Flux Results Obtained During Departure from Nucleate Boiling Testing"
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- Overall ML approach was presented at FPUM in September 2021, updates will be presented herein

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DNB Correlation Development Process

- For PWR design applications, DNB predictive model is currently determined empirically based on test data for complicated fuel assembly component designs
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Machine Learning Model Development Update

- Different path with improved model development capability than what was presented at the last update meeting

- Continue to focus on [
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ML-Based DNB Correlation Inputs

- Input parameters similar to existing DNB correlations
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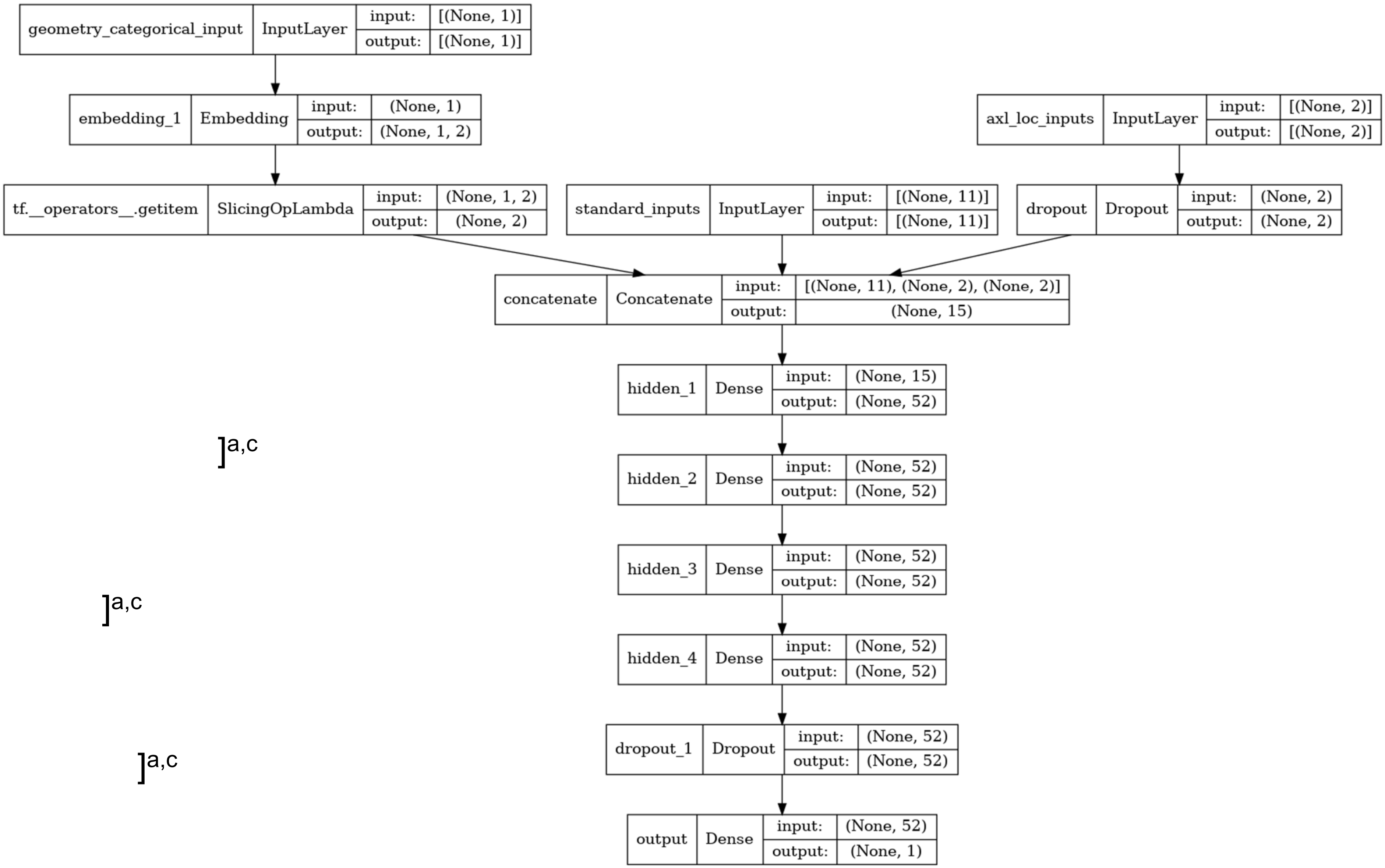
Model Architecture



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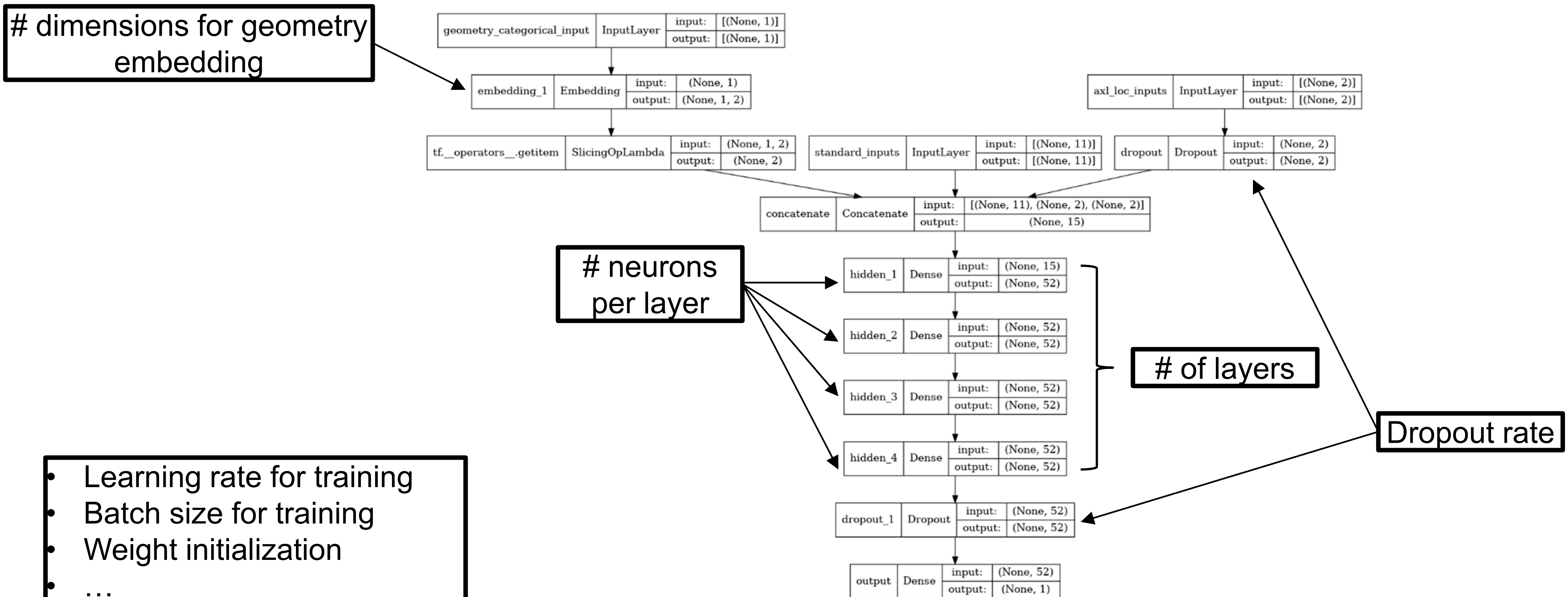
Hyperparameter Tuning



- Learning rate for training
- Batch size for training
- Weight initialization
- …

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Dropout Layers

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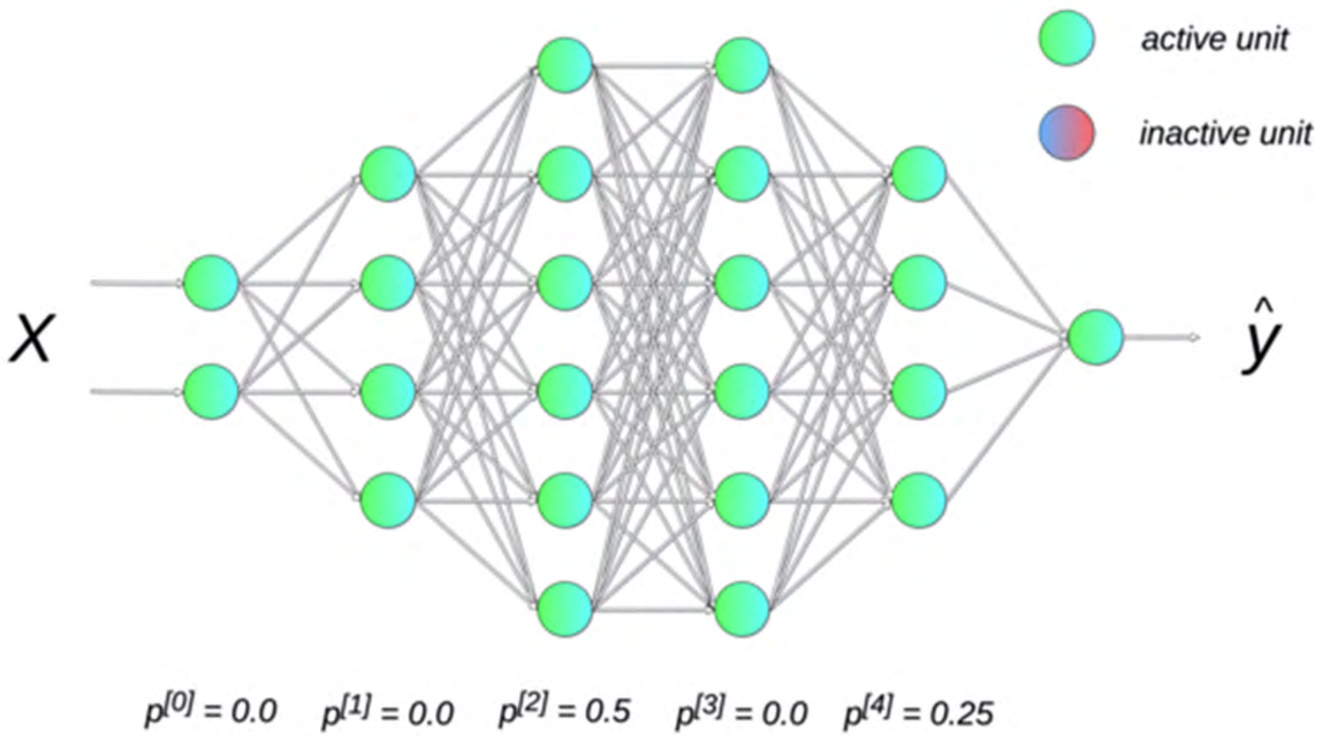

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ML-Based DNB Correlation Evaluation

- Current best practices and guidelines are evaluated or followed for ML DNB predictive model development
  - NUREG-KM-0013 (Draft) reviewed
  - Available algorithms and optimization schemes explored
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  - NUREG-2261 (Draft)
- Sensitivity check for Physics-Informed ML model
- Uncertainty quantification (ongoing development of approach)

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ML-Based DNB Correlation Application Process

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Initial ML Model & Results for OFA

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Sensitivity Checks

- Physics informed model sensitivity checks ensure CHF predictions consistent with physical behaviors
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Summary

We are continuing to pursue Machine Learning technology to assist in new DNB Correlation Development:

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We are formulating our Long-Term Correlation Development approach for the 17x17 Fuel Products:

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Questions/Comments?

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Westinghouse PWR Fuel Performance Update

September 2022

Jason Smith, Manager
Product Performance Engineering

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Agenda

- **Fuel Performance Update**
- Changing in Performance Trends
  - Improvements in Debris Mitigation
- [ ] a,c Leaker Investigation
- [ ] a,c Leaker Investigation
- [ ] a,c Fuel Rod Visual Anomalies
- Summary

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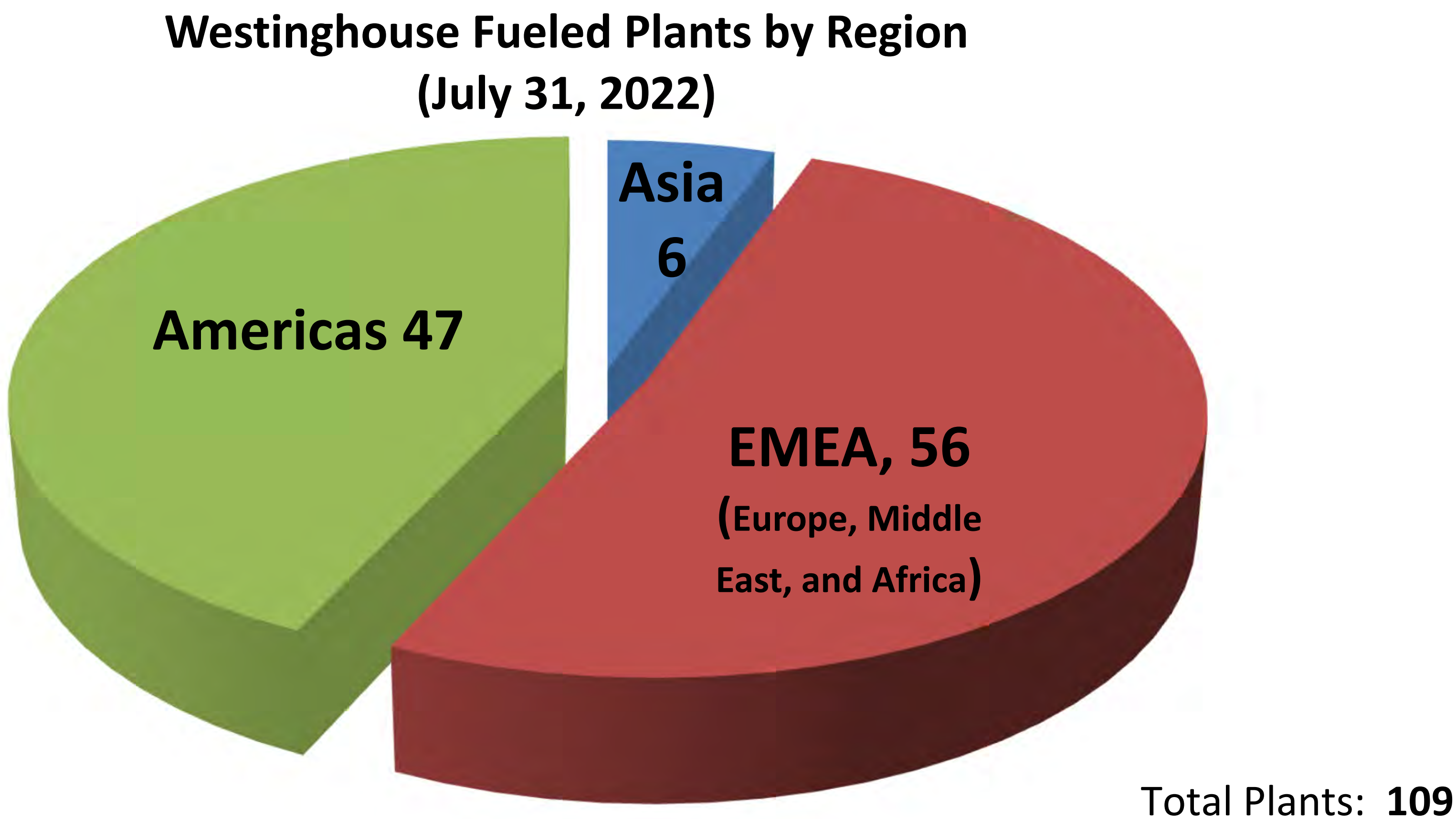
Westinghouse Fueled Plants by Region



Global Fuel Reliability Process Required to Achieve and Maintain 100% Leak-Free, Issue-Free Fuel

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Nuclear Fuel Reliability Improvement Progress As Of July 31, 2021

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Historical Performance of Westinghouse Fueled Plants

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Leaking Plants, July 31, 2022 Worldwide

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Historical Performance of Plants Currently Leaking As of July 31, 2022

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Driving to Flawless Fuel Through Design – Current Status (July 31, 2022)

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Agenda

- Fuel Performance Update
- **Changing in Performance Trends**
  - **Improvements in Debris Mitigation**
- [ ] a,c Leaker Investigation
- [ ] a,c Leaker Investigation
- [ ] a,c Fuel Rod Visual Anomalies
- Summary

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Historical Trend in Number of Leaking Fuel Rods

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Changing in Performance Trends (PWR)

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Advanced Debris Protection Program

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Advanced Debris Filter Bottom Nozzle (ADFBN)

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Agenda

- Fuel Performance Update
- Changing in Performance Trends
  - Improvements in Debris Mitigation
- **[ ] a,c Leaker Investigation**
- [ ] a,c Leaker Investigation
- [ ] a,c Fuel Rod Visual Anomalies
- Summary

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[ ] a,c Leaker – Initial Actions

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[ ] a,c Leaker – Actions During Outage

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[ ] a,c Leaker – Actions After Outage

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Agenda

- Fuel Performance Update
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- [ ] a,c Leaker Investigation
- **[ ] a,c Leaker Investigation**
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- Summary

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[ ] a,c Leaker

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[ ] a,c Planned Scope

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Agenda

- Fuel Performance Update
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- [ ] a,c Leaker Investigation
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- Summary

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[ ] a,c Fuel Rod Visual Anomalies

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Agenda

- Fuel Performance Update
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  - Improvements in Debris Mitigation
- [ ] a,c Leaker Investigation
- [ ] a,c Leaker Investigation
- [ ] a,c Fuel Rod Visual Anomalies
- **Summary**

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Summary

- Robust Westinghouse fuel designs performing well

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- Goal is 100% leak free performance through continuous improvement and strong partnership with industry

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Questions?

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Westinghouse BWR Fuel Performance Update

Kevin Lasswell - *Americas BWR Product Manager*

Michael Boone - *Americas BWR Product Manager*

September 15, 2022

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Agenda

- BWR Fuel Performance Update
- **TRITON11**® Fuel Update
- BWR Codes/Methods Update
- Topical Reports Planned for Submission to NRC

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BWR Primary Failure Statistics
10X10 BWR Fuel Designs using liner cladding

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TRITON11 Fuel

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TRITON11 LTAs in Europe

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StrongHold AM Filter

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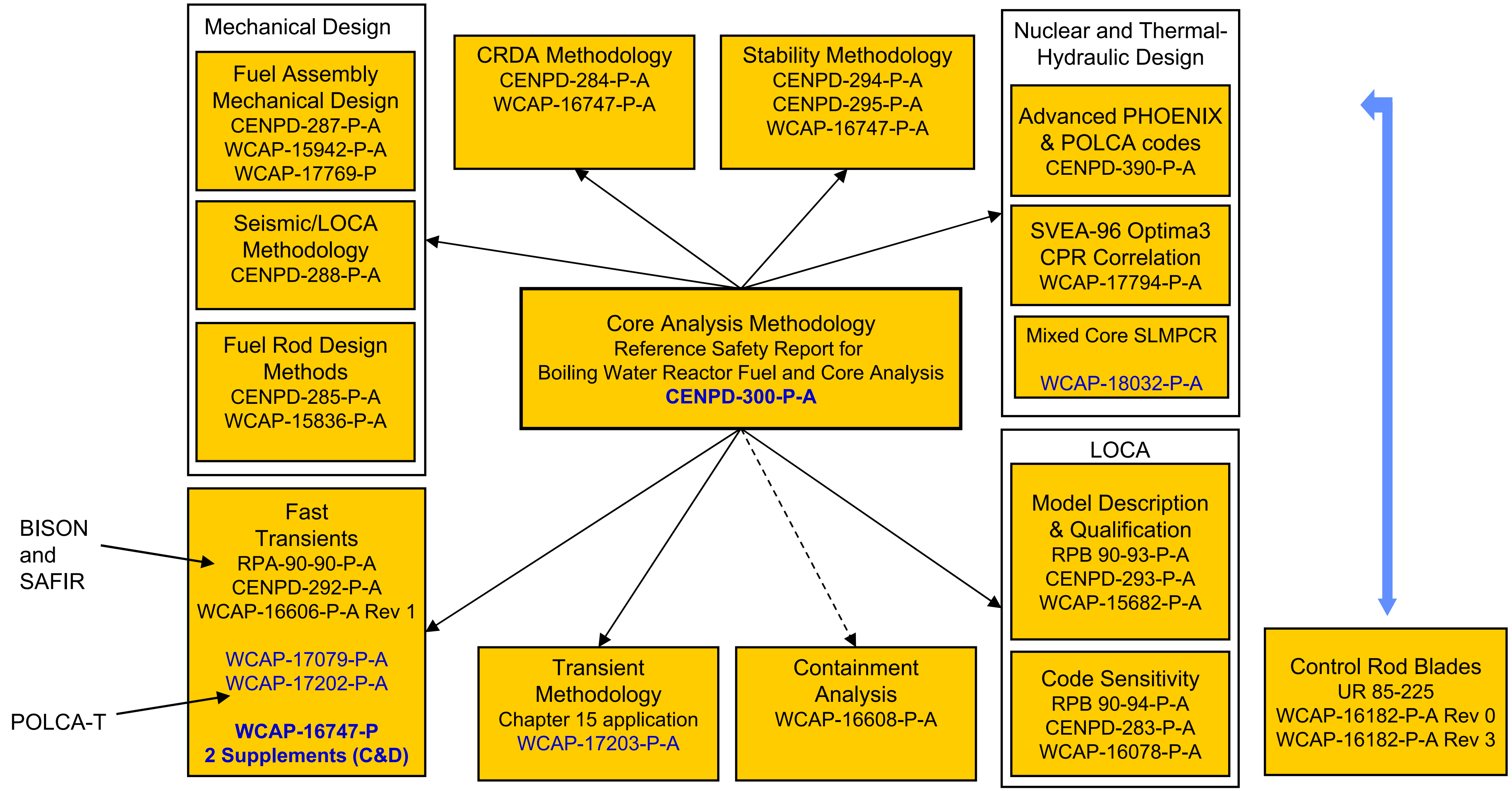
Westinghouse BWR Methodology USNRC-licensed package



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Status of Development Projects

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Enhancing the capabilities and reliability of Westinghouse BWR Core Analysis Tools in support of TRITON11 reloads

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TRITON11 – Projected Topical Report Submission

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Questions

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Westinghouse **VISION & VALUES**

together

we advance technology
& services to power a
clean, carbon-free future.

Customer Focus & Innovation

Speed & Passion to Win

Teamwork & Accountability

Safety • Quality • Integrity • Trust

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Additive Manufacturing at Westinghouse

2022 Fuel Performance Update Meeting

David Huegel

September 2022

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Overview

- Westinghouse AM Objectives
- Summary of AM at Westinghouse
- AM Development at Westinghouse
- First AM Nuclear Fuel Component Installed in Commercial Reactor
- First installed AM 3D printed BWR nuclear fuel debris filter
- Westinghouse Developed AM Nuclear Fuel Components
- Westinghouse AM Tooling Development
- Westinghouse AM Bottom Nozzle for PWR
- AM Development Partnering with Industry/ Academia
- Q&A

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Additive Manufacturing at Westinghouse

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Advanced Manufacturing Objectives

- **Improve industry competitiveness, through the development and implementation of advanced manufacturing (AM) technologies**
  - Drive cost reductions in manufacturing
  - Enable new products and services that provide innovative customer solutions
  - Leverage external funding sources and collaborative development

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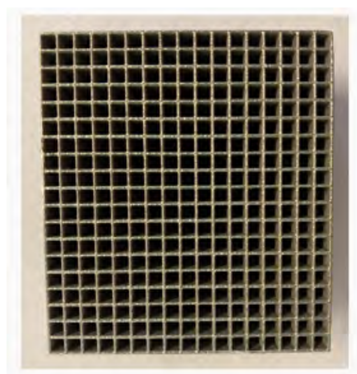
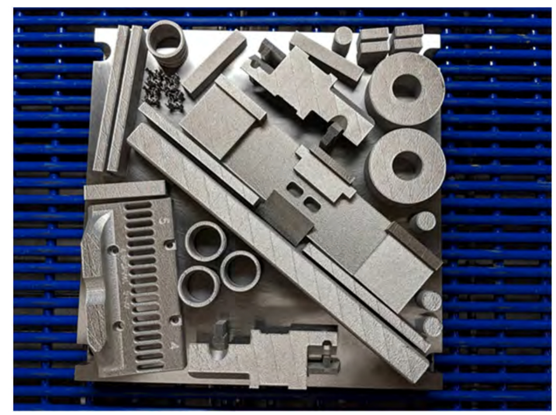
Thimble Plugging Device Direct Metal Laser Sintering



Advanced AM BWR Bottom Filter



Tooling - AM Laser Powder Bed Fusion

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Additive Manufacturing at Westinghouse

- Additive Manufacturing will have a big impact in Nuclear:
  - Cost Effect
  - Improve Performance and Reliability
  - Improve Delivery and Schedule
- Westinghouse is fully invested in the AM technology:
  - Continue to performed significant testing on 3D parts (with and without radiation effects)
  - Utilizing 3D printing for tooling for manufacturing
  - Implemented a 3D AM part in reactor to gain experience
  - Building/designing numerous parts with AM for eventual employment in a nuclear reactor (grids, nozzles, etc.)

Our Goal is for AM to Help Transform the Nuclear Industry

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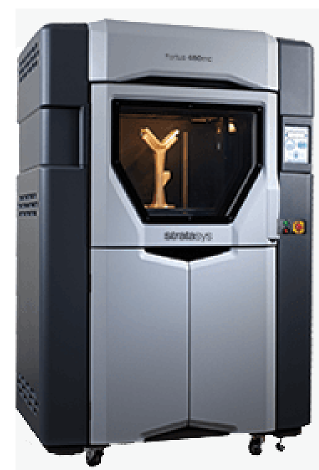
Additive Manufacturing – Westinghouse Equipment

- Westinghouse owns one (1) EOS M 290 machine for printing in metal with access to additional machines at the same facility
  - Currently printing in:
    - Alloy 718
    - SS Types: 316L, 304,17-4 PH and MS-1
    - Copper and Aluminum
  - Build volume 250mm x 250mm x 325mm (9.85 x 9.85 x 12.8 in)
- Additively Manufactured (3D Printed) Plastic Parts

- CFFF installed a high quality Fortus 450 polymer FDM printer.
- Build volume 406mm x 355mm x 406 mm (16 x 14 x 16in)
- Variety of ABS and Nylon materials



Westinghouse AM Equipment

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Additive Manufacturing Development at Westinghouse

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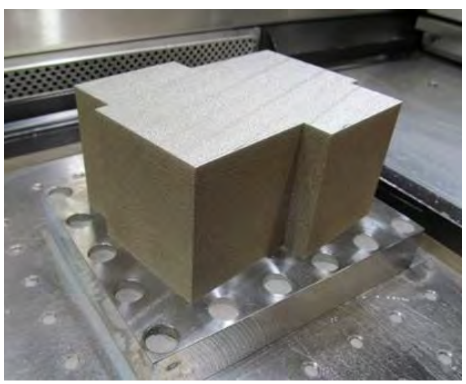
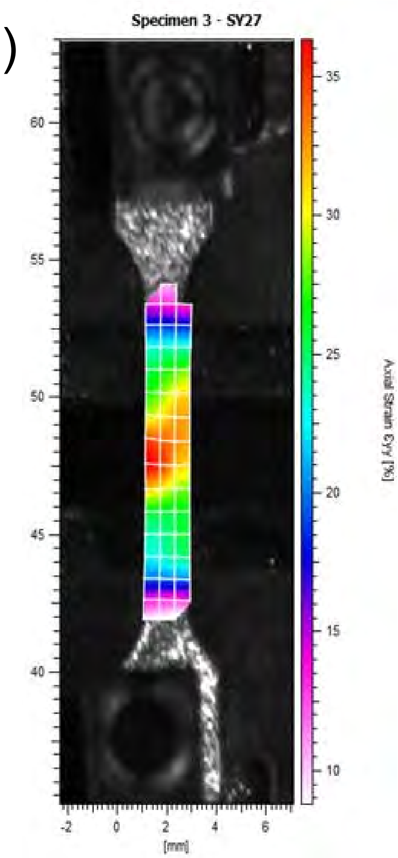
AM Materials Development

- **Westinghouse has funded material development and irradiation performance testing for 316L SS, Ni Alloy 718 and Zr**
  - Produced AM block and micro-tensile test specimens
  - Irradiating materials in MIT's test reactor (Oct. 2014 → 2018)
  - Completing post-irradiation examination (PIE) at Westinghouse Churchill lab (SS316L and Alloy 718 completed, Zr PIE DOE funded)
  - AM SS316L irradiation performance consistent with wrought
  - Alloy 718 material behaved consistent with wrought material. (Use of Alloy 718 in a fuel component discussed later).





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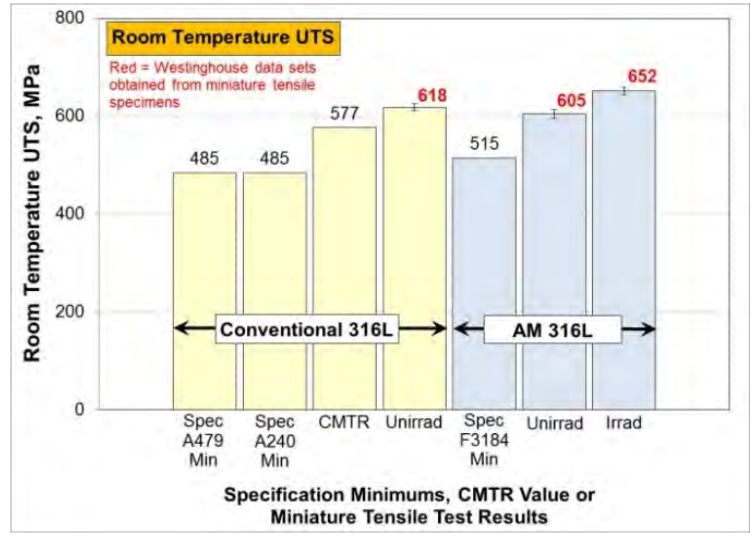
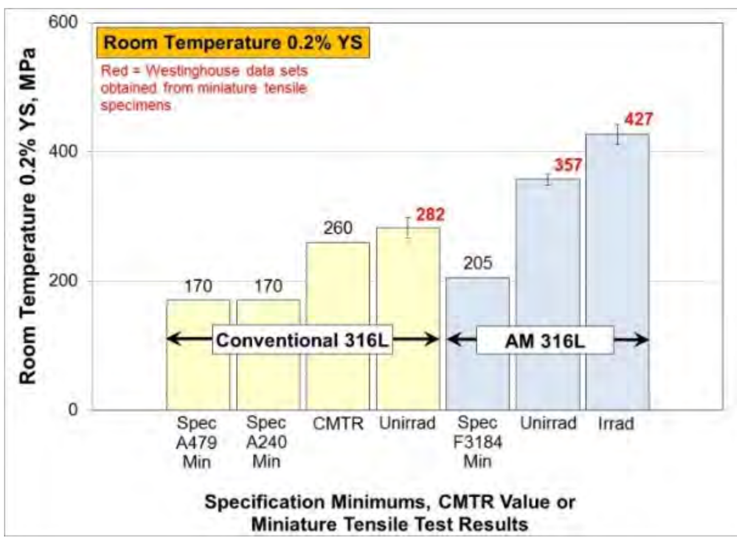
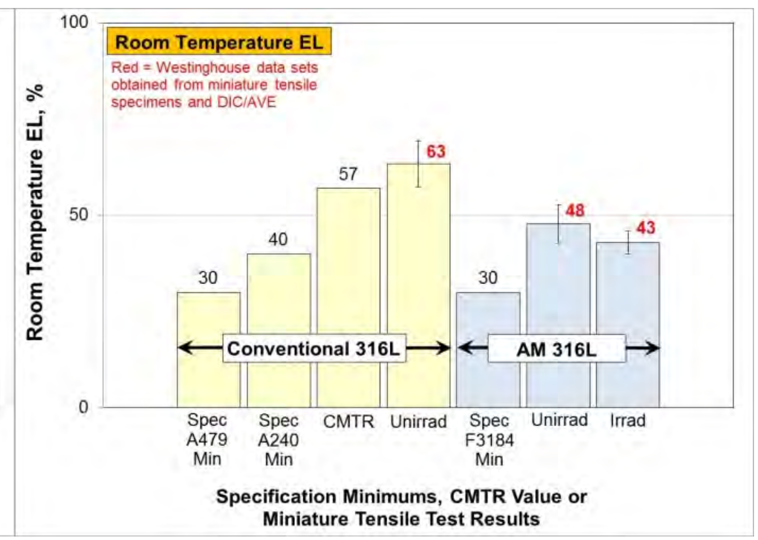
AM Materials Development

- **SS316L samples have been tested and evaluated for mechanical properties**
  - The absolute values for the AM material Ultimate Tensile Strength (UTS), 0.2% Offset Yield Strength (YS) and percent elongation (% EL) were as expected and consistent with conventional material
  - Tensile strengths, both UTS and YS increased with irradiation as expected
  - % EL went down with irradiation as expected







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First AM Nuclear Fuel Component Installed in Commercial Reactor

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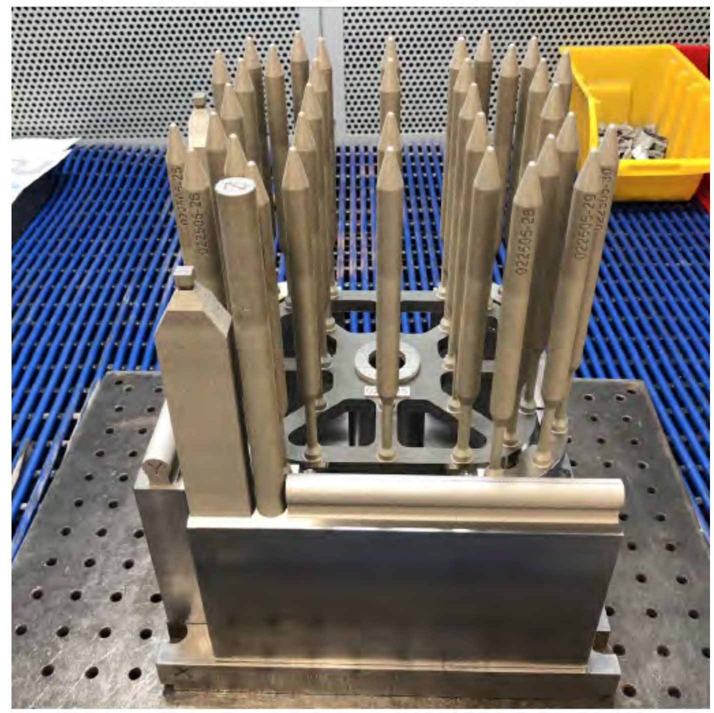
First AM Component (TPD) Installed at Commercial Reactor

- AM Thimble Plugging Device (TPD) first AM fuels component successfully installed in a commercial reactor (Byron 1 March 2020)
  - Low Risk Component, moderate complexity
- Westinghouse met with NRC in May 2019 at the Westinghouse Rockville offices and discussed AM TPD in detail prior to installation.
  - Implemented using the 50.59 process



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AM Component (TPD) Inspection Summary

- During the Byron Cycle 25 outage, an inspection of the AM TPD was performed and included:

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- The AM TPD was then re-inserted back into the core for a second cycle of irradiation.

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AM Component (TPD) Inspection Summary

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First AM BWR Bottom Filter Installed in Commercial Reactors

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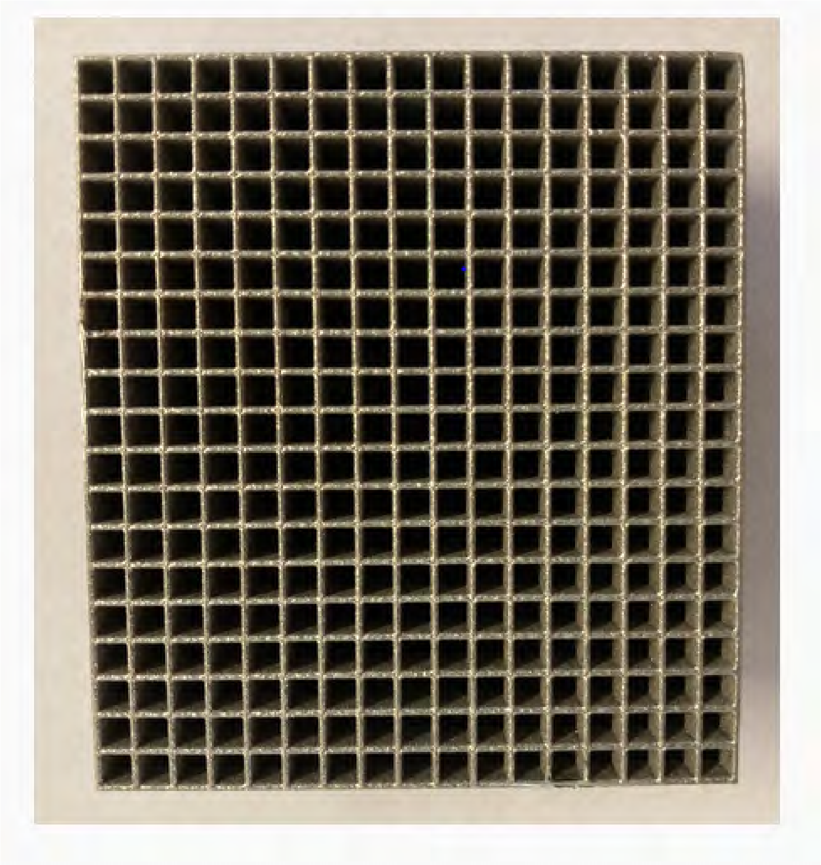
First AM BWR Bottom Filter Fuel Component Installed

- Westinghouse created the **StrongHold** AM filter in close cooperation with Teollisuuden Voima Oyj (TVO) and Oskarshamn (OKG)
- The **StrongHold** AM filter is a fully manufactured 3D printed bottom nozzle which offers enhanced capture features to prevent debris from entering the fuel assembly bundle region where it could potentially damage the fuel cladding.
- Debris testing demonstrated that the **StrongHold** filter performed better tha the existing **TripleWave+** bottom filter
- **StrongHold** AM filters were recently installed in Olkiluoto Unit 2 in Finland and Oskarshamn Unit 3 in Sweden



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Westinghouse Developed AM Nuclear Fuel Components

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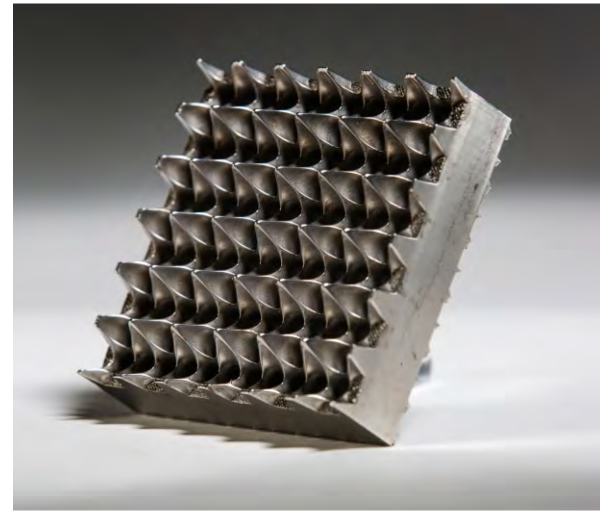
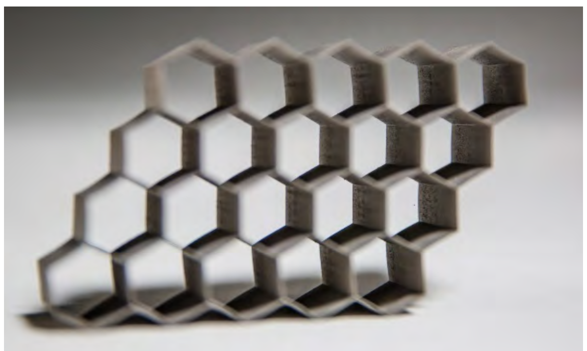
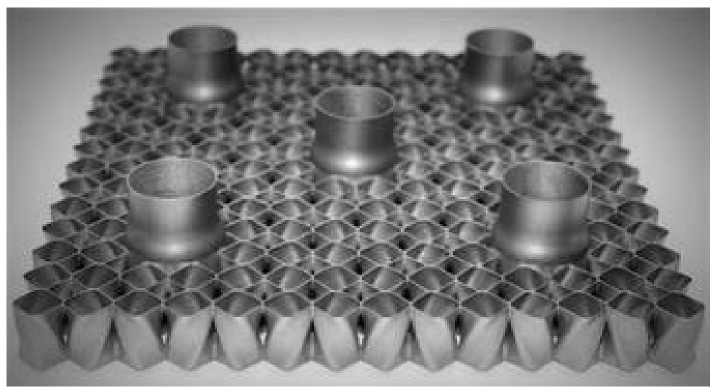
AM Fuel Structures - Grids

- Improved flow characteristics are possible with AM resulting in better heat transfer from fuel rods to reactor coolant for better performance.
- Stronger, more efficient support of fuel rods with better mixing characteristics and less GTRF.

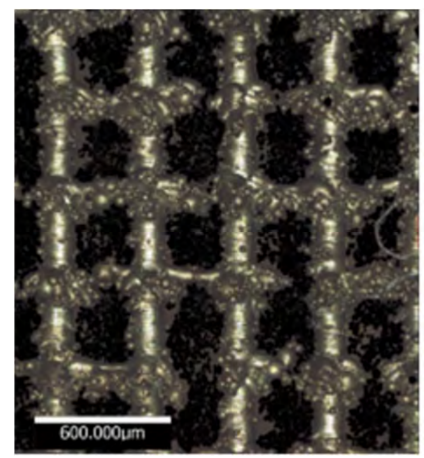






Items requiring further investigation:

- Corrosion characteristics in PWR chemistries
- Mechanical strength of small features



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Westinghouse AM Tooling Development

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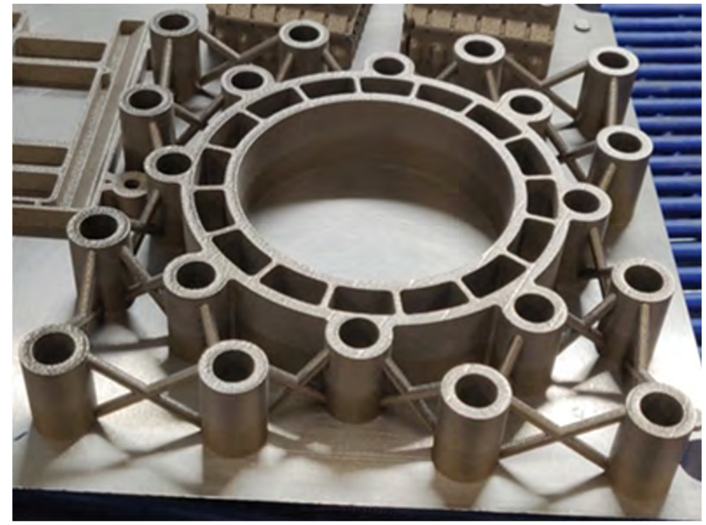
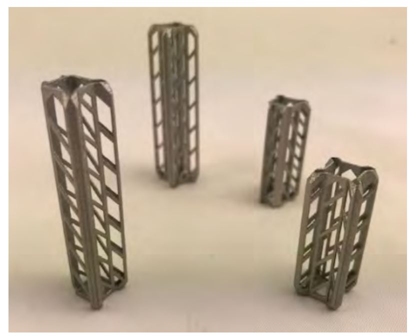
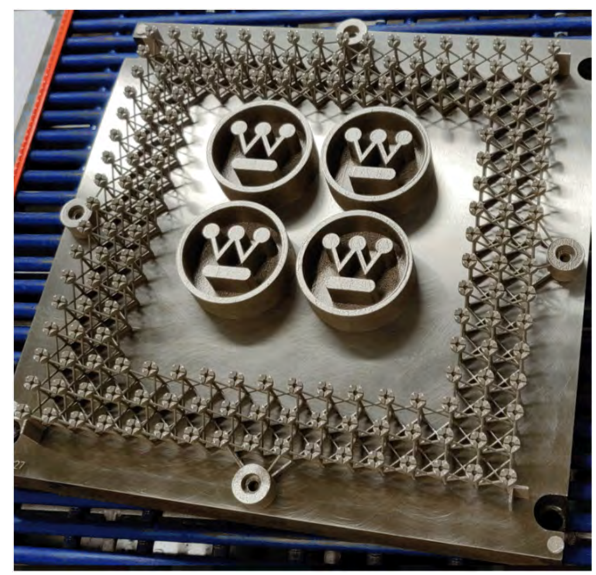
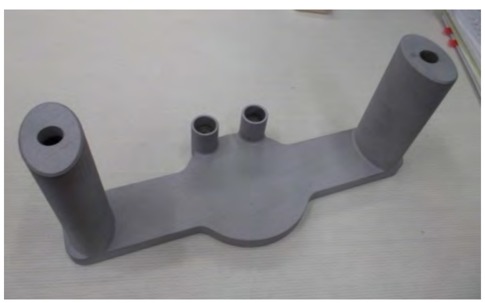
Tooling for Manufacturing

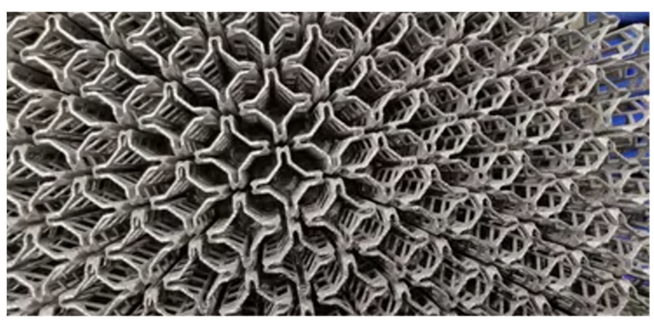
- **Immediate benefit from tooling applications**
  - Lower the costs and improve performance
- **Improved safety for operators**
  - Reduction of leak points
  - Two hands touch control
  - Ergonomic designs resulting in less fatigue injuries











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Westinghouse Developed AM PWR Bottom Nozzle

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Westinghouse AM Bottom Nozzle

- AM development of the AM PWR bottom nozzle
- Debris Testing of AM PWR Bottom Nozzle
- GSI-191 Testing of AM PWR Bottom Nozzle
- Westinghouse Documentation of the AM Process (for PWR BN)
- Licensing of an AM PWR Bottom Nozzle

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AM Fuel Bottom Nozzle

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AM Fuel Bottom Nozzle – Debris Testing

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AM Fuel Bottom Nozzle - Mesh Structural Testing

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AM Fuel Bottom Nozzle - Mesh Structural Testing

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AM Fuel Bottom Nozzle - GSI-191

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AM Fuel Bottom Nozzle - GSI-191

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AM Fuel Bottom Nozzle - GSI-191

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AM Fuel Bottom Nozzle - GSI-191

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AM Fuel Bottom Nozzle Documentation

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AM Fuel Bottom Nozzle Licensing

- In the draft NRC 50.59 guidance for AMTs, it is noted that:

  "Since AMT fabrication involves a significant change to the material and manufacturing process when compared to traditional fabrication methods, an AMT item is not identical to the original and therefore should not be considered a like-for-like replacement. "

  "…..the licensee's technical evaluation process might include an equivalency evaluation to address the impact of the change in design, material and manufacturing on the ability of the AMT item to perform its intended design function."

  "If there is no adverse impact on the design function, the AMT item may be considered "equivalent" to the original in its ability to perform its intended design function."

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AM Fuel Bottom Nozzle Licensing

- NRC guidance for Laser Powder Bed Fusion

  The NRC guidance for LPBF gives detailed information on what should be addressed when using this technology for AMTs. These areas include:

  A. LPBF Machine process control

  - Machine calibration is vital for fabrication replication, ensuring correct laser power and beam shape, and ensuring atmospheric quality control in addition to helping meet geometric tolerances.
  - Westinghouse:
    - Ensures that there is careful control of the LPBF file preparation to ensure that there is accurate process control.
    - Documents the LPBF machine qualification, calibration, documents the key process control parameters, such as the CAD model, the EOS print file, etc.
    - Performs a product qualification plan/report for all AM LPBF produced components to be placed in a reactor.

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AM Fuel Bottom Nozzle Licensing

- NRC guidance for Laser Powder Bed Fusion (cont.)

  B. LPBF Powder Quality

  - Powder contamination is a critical issue that may adversely affect material properties and the process by introducing oxides and altering the chemical composition. Powder reuse acceptance/rejection depends on routinely sampling and characterizing powder after sieving.
  - Westinghouse:
    - Documents the material specifications for the powder as well as the control of the powder.
    - Uses commercial powder and testing on the final AM product.
    - Performs ongoing confirmatory testing as part of the Qualification plan/report to ensure that powder quality is maintained at a high level.

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AM Fuel Bottom Nozzle Licensing - LUAs

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AM Fuel Bottom Nozzle Licensing - Region

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Additive Manufacturing Development Partnering with Industry/Academia

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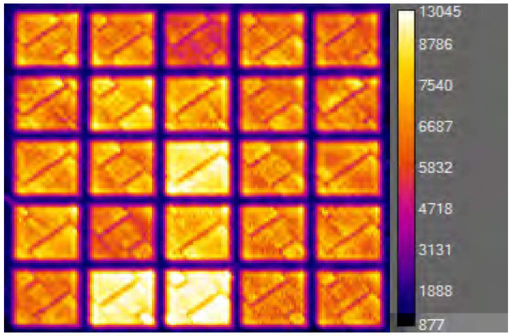
Additive Manufacturing – Current Projects

- Department of Energy – *DE-FOA-0001281* - NEET-1- "**Integrated Computational Materials Engineering (ICME) and In-situ Process Monitoring for Rapid Qualification of Components Made by Laser-Based Powder Bed Additive Manufacturing (AM) Processes for Nuclear Structural and Pressure Boundary Applications**"
  - Project Lead Principal Investigator (PI) is EPRI
  - Project Co-PI's – ORNL, Rolls Royce, and WEC
  - Completed in early 2020 with ASME code case submission for 316L



Qualification of AM Components

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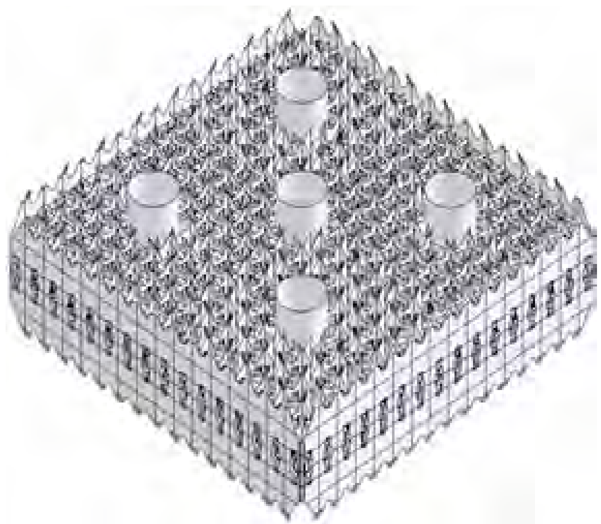
Additive Manufacturing – Current Projects

- Department of Energy – *DE-FOA-0001858* – ARPA-E

"ADDITIVE MANUFACTURING OF SPACER GRIDS FOR NUCLEAR REACTORS"

- Project Lead Principal Investigator (PI) is CMU (Carnegie Melon University)
- Initiated in 2019
- Effort to demonstrate feasibility of additively manufacturing thin-walled components for reactor use.
- Currently, thin-walled materials (Zirc based and Alloy 718) are commonly used in the manufacturing of grids.



Exploring Advanced Reactor Components

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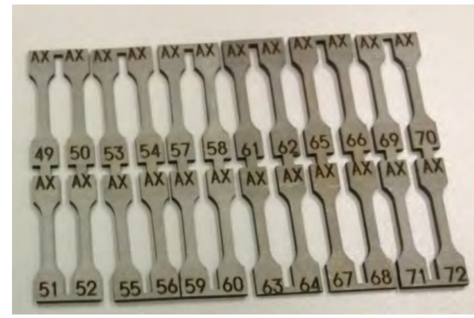
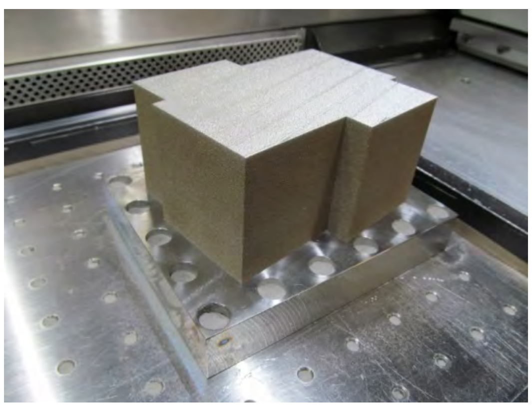
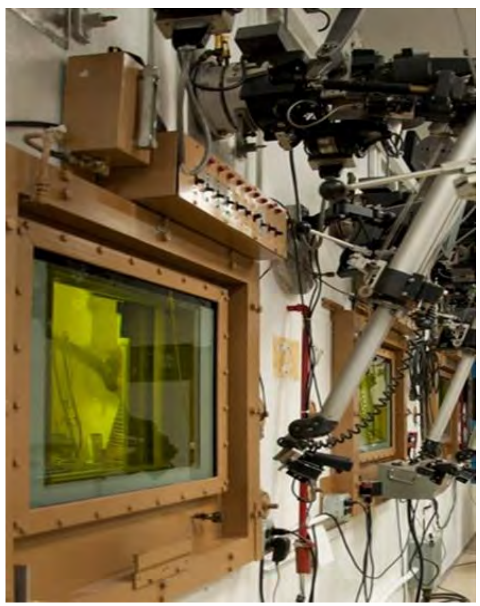
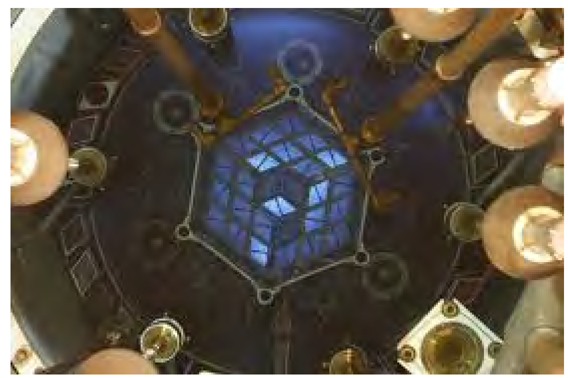
Additive Manufacturing – Current Projects

- Department of Energy – DE-FOA-0001515 - NSUF-2: Nuclear Science User Facilities Access Only - Radiation Effects on Zirconium Alloys Produced by Powder Bed Fusion Additive
  - Project Lead – WEC
  - 3 year program completed in 2021
  - Demonstrated feasibility of AM zircaloy









First of a Kind Research in AM Zirconium Alloys

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Additive Manufacturing – Current Projects

- Development of Zr-4 for Laser Powder Bed Fusion systems
- Targeting spacer grids with a secondary medical devices market
- **Challenges:**
  - Reactivity of zircaloy powder
  - Yield rates of the atomization processes

Continuing Development of AM Zirconium Alloys

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Q & A

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Cobalt-60 Production in Westinghouse PWRs

Nuclear Beyond Power

Keith Newmyer, Project Manager
Zachary Harper, Manager, Licensing Engineering

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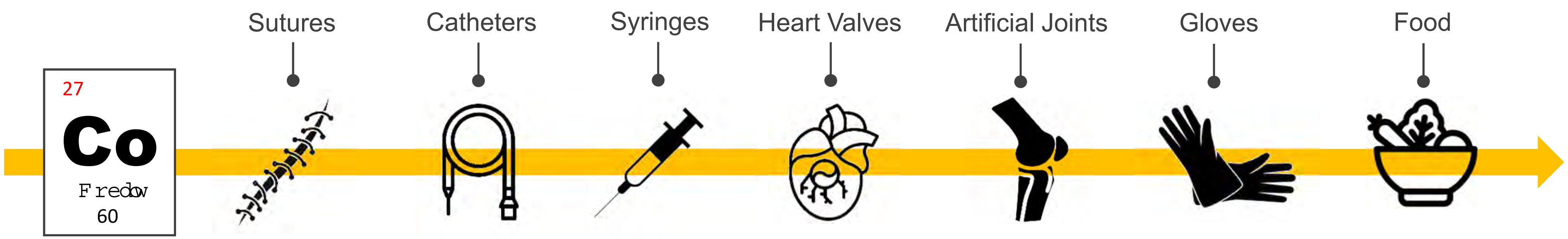
Safeguarding Healthcare

U.S. Infrastructure Dependent on Reliable Cobalt-60 Supply



45%

Of all single-use medical supplies and devices used globally are sterilized by cobalt-60 (gamma)

FDA U.S. FOOD & DRUG ADMINISTRATION

Of the more than two million medical devices listed in the U.S. FDA Global Universal Device Identification Database (GUDID), 40% are provided as sterile to users and patients

LARGE DEVICE MARKET CRITICALLY IMPORTANT TO U.S. AND GLOBAL HEALTHCARE

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Cobalt-60 Production Scheme

Production Processes & Logistics, Key Activities and Cost Considerations, and Input & Output to and from the Reactor

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Cobalt-60 Production Scheme

High-Level Process Flow Diagram

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Cobalt-60 Production Logistics

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Cobalt-60 Production Logistics

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Cobalt-60 Production Logistics

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Cobalt-60 Production Logistics

Cobalt Harvesting Timelines

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Cobalt-60 Licensing

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Licensing

- Multiple technical exchange meetings with the NRC (2020 and 2022)

- Westinghouse will work with different utility partners to submit site-specific License Amendment Requests (LARs)
  - Co-60 is a byproduct material that is covered under Part 30
  - LAR will cover changes to the Licensing basis (Operating License, and or Technical Specifications [TS])
  - Additional updates to the Final Safety Analysis Report and/or TS Bases
  - Multiple Analyses of Record will be impacted (Nuclear Design, LOCA, Source Term, radiological dose, SFP criticality)

- NRC should anticipate LAR pre-submittal meetings [

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eVinci™ Micro Reactor

Anthony Schoedel
Manager, Advanced Reactors Licensing Engineering

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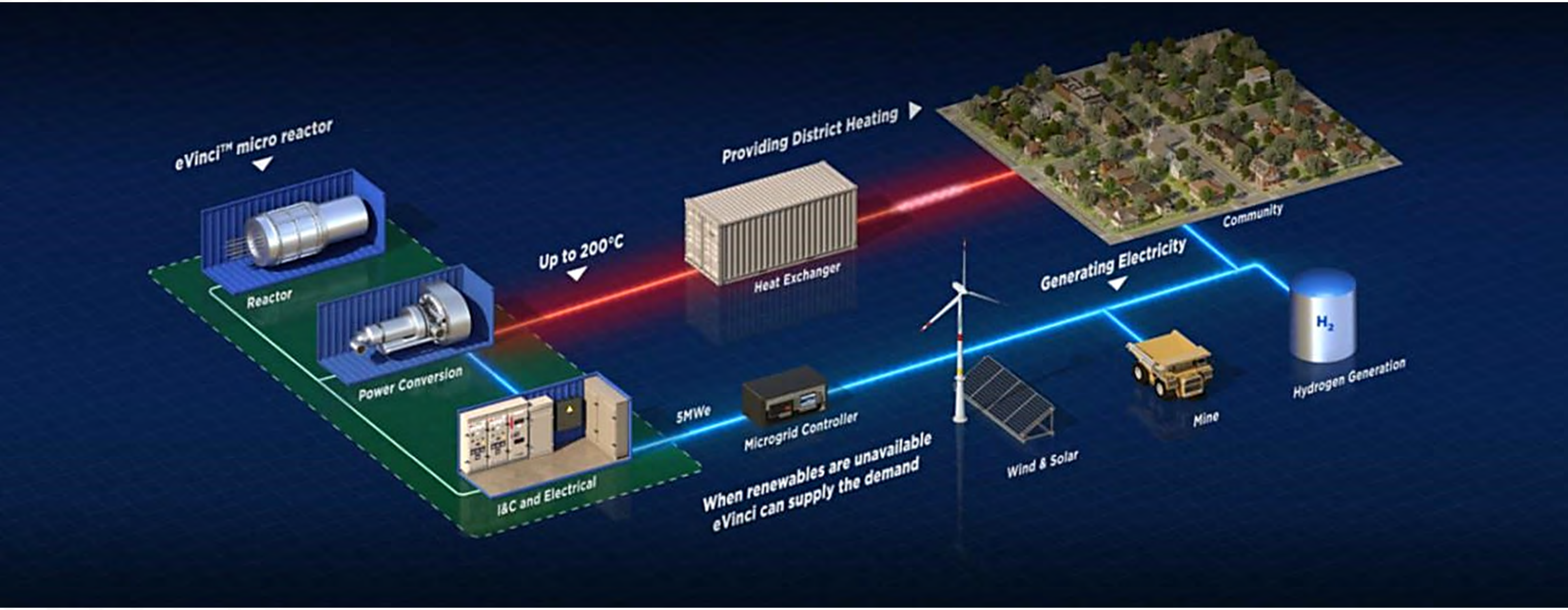
Revolutionary Technology



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The eVinci™ microreactor will revolutionize availability of carbon-free heat and electricity

Primary missions:

- Provide competitive and resilient power to targeted markets with superior reliability and minimal maintenance
- Size allows for transportability - allowing rapid installation and elimination of on-site fuel handling and storage

Development status:

- Progressing through development and testing program
- Engaged with multiple early adopters
- Pre-licensing engagements with US NRC and CNSC Vendor Design Review

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eVinci™ microreactor

Key Features

Nuclear battery designed for reliable electricity and heat generation

Technical Capabilities

- 5 MW_e with ~7MW_{th} @ 350°F waste heat
- ~13.5MW_{th} @ >1300°F heat only
- Effective cogeneration (power & heat) nuclear battery
- Minimum 8-year refueling cycle
- Transportable for ease of installation and elimination of spent fuel storage on site
- Cost-competitive plant lifecycle
- Minimal onsite personnel
- Mature technology, manufacturing, and regulatory readiness
- High-speed load following capability

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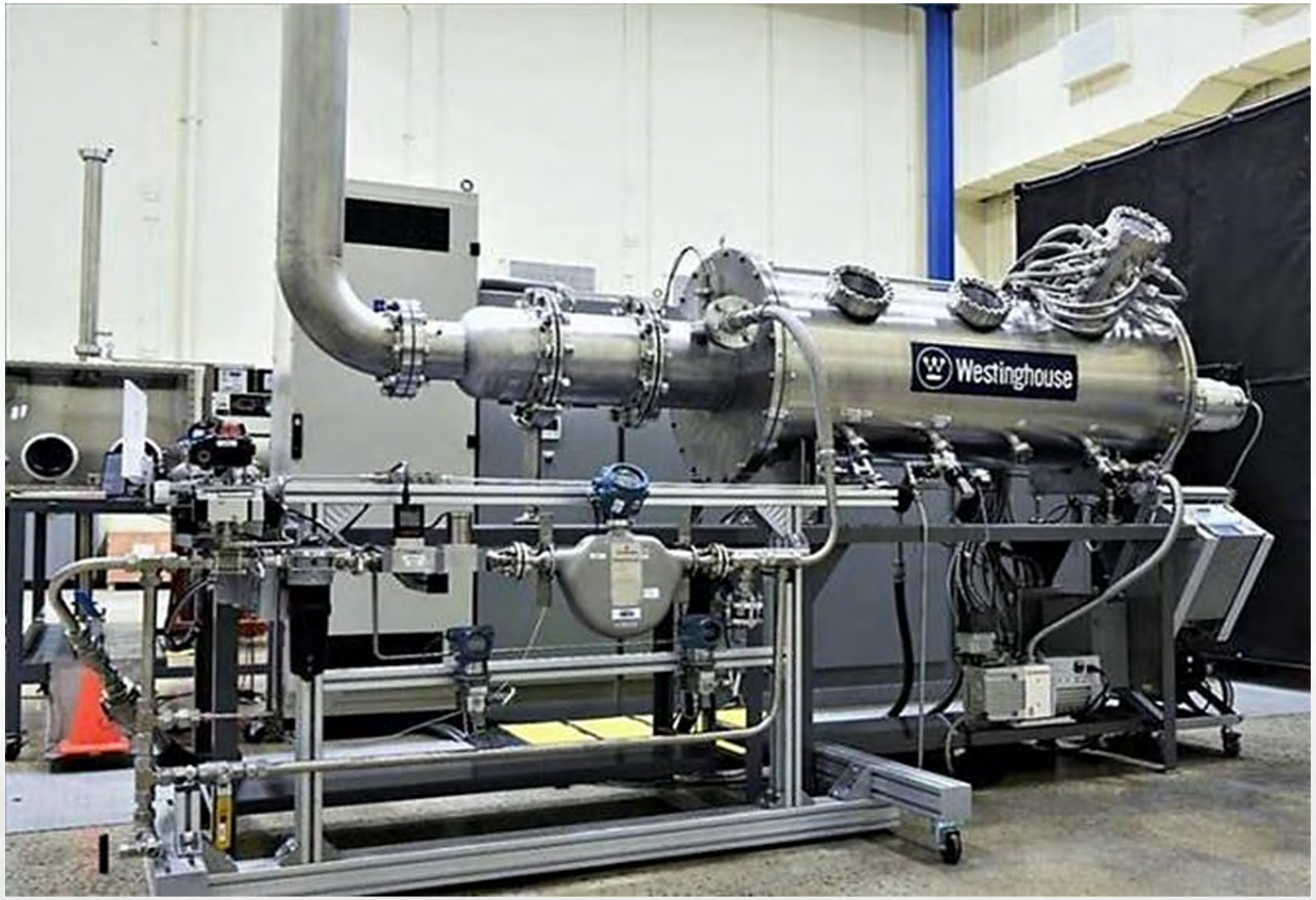
Development and Testing



Test Chamber

Heat Pipes

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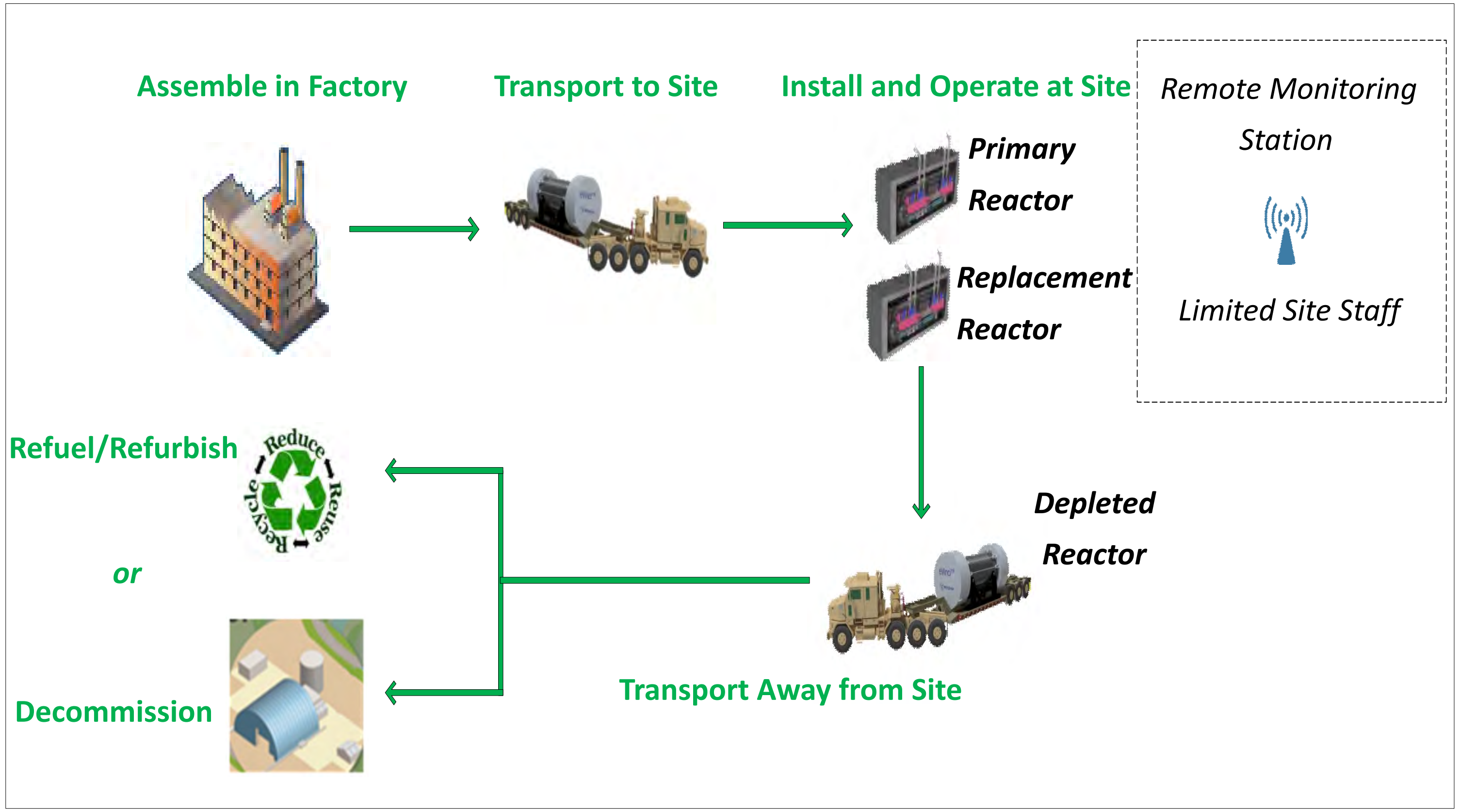
eVinci micro reactor Deployment

Test Reactor for Safety Feature Performance Demonstration

Test Reactor - Testing, data collection, and analysis

Standard Design Certification per 10 CFR Part 52 Subpart B

eVinci Micro Reactor Deployment



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https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/evinci.html

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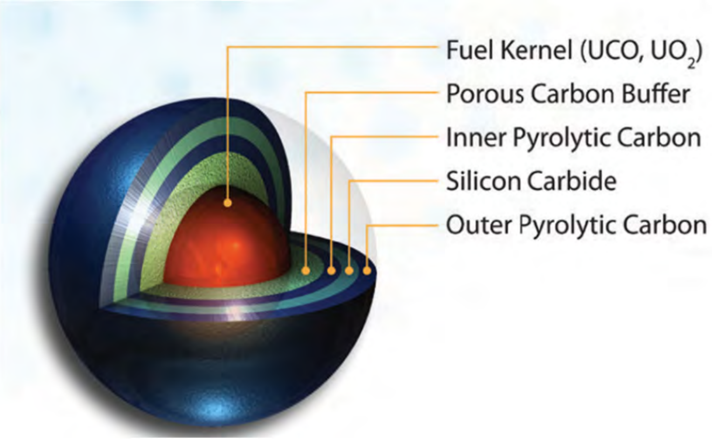
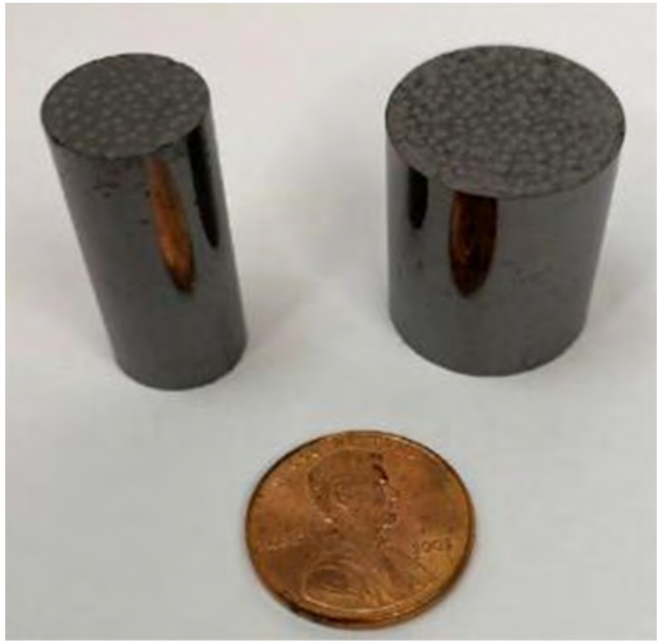
eVinci Fuel Design
TRISO Fuel

- Uranium Oxycarbide (UCO) in a tri-structural isotropic (TRISO) fuel form
- UCO limits oxygen activity, reducing CO and CO_2 generation and gas pressure
- HALEU (<19.75wt% ^{235}U) fuel
- Buffer: low-density porous pyrolytic carbon (PyC) coating layer
- IPyC: high-density first load-bearing layer against the pressure exerted by the Fission Product (FP)
  - Retains gaseous FPs but loses effectiveness at high temperatures to retain metallic FPs
- SiC: structural skeleton of the TRISO particle
  - Third layer for FP retention, including metallic FPs at high temperatures
  - Sufficient strength to withstand internal pressure during irradiation
- OPyC: the final barrier for FPs
  - Mechanical protection for the SiC layer
  - Both OpyC and IPyC shrink initially during irradiation leading to compression of the SiC layer, reducing tensile stress on this layer

TRISO Fuel is only High temperature fuel that has regulatory acceptance and extensive qualification basis





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