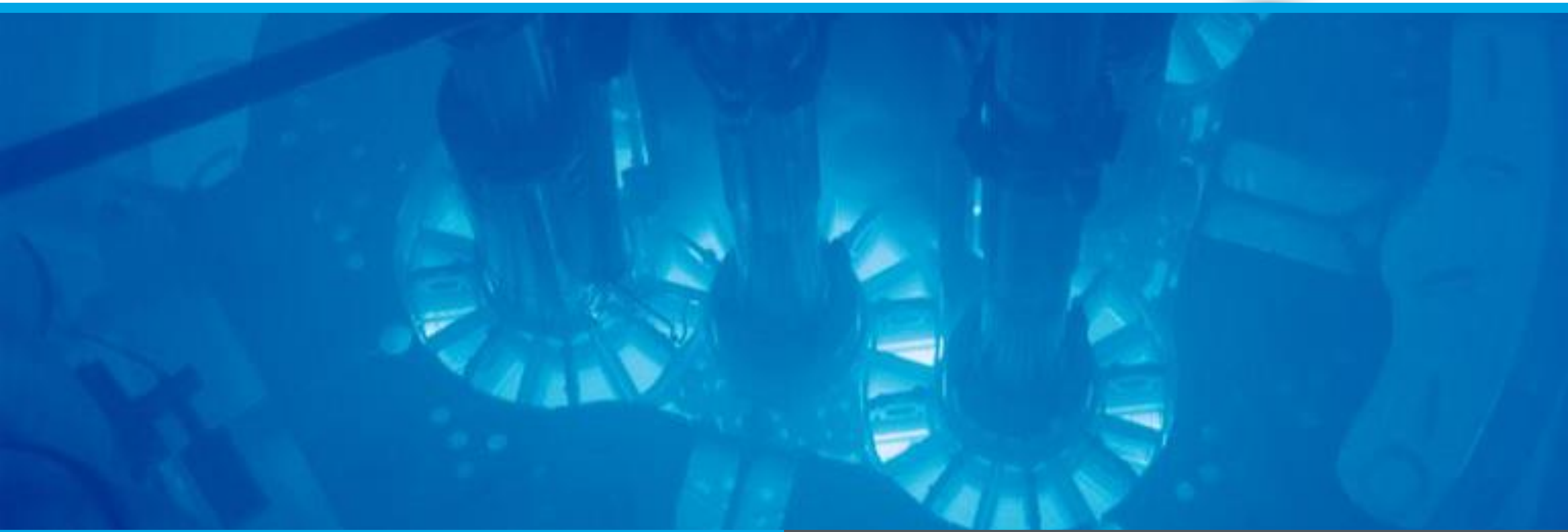


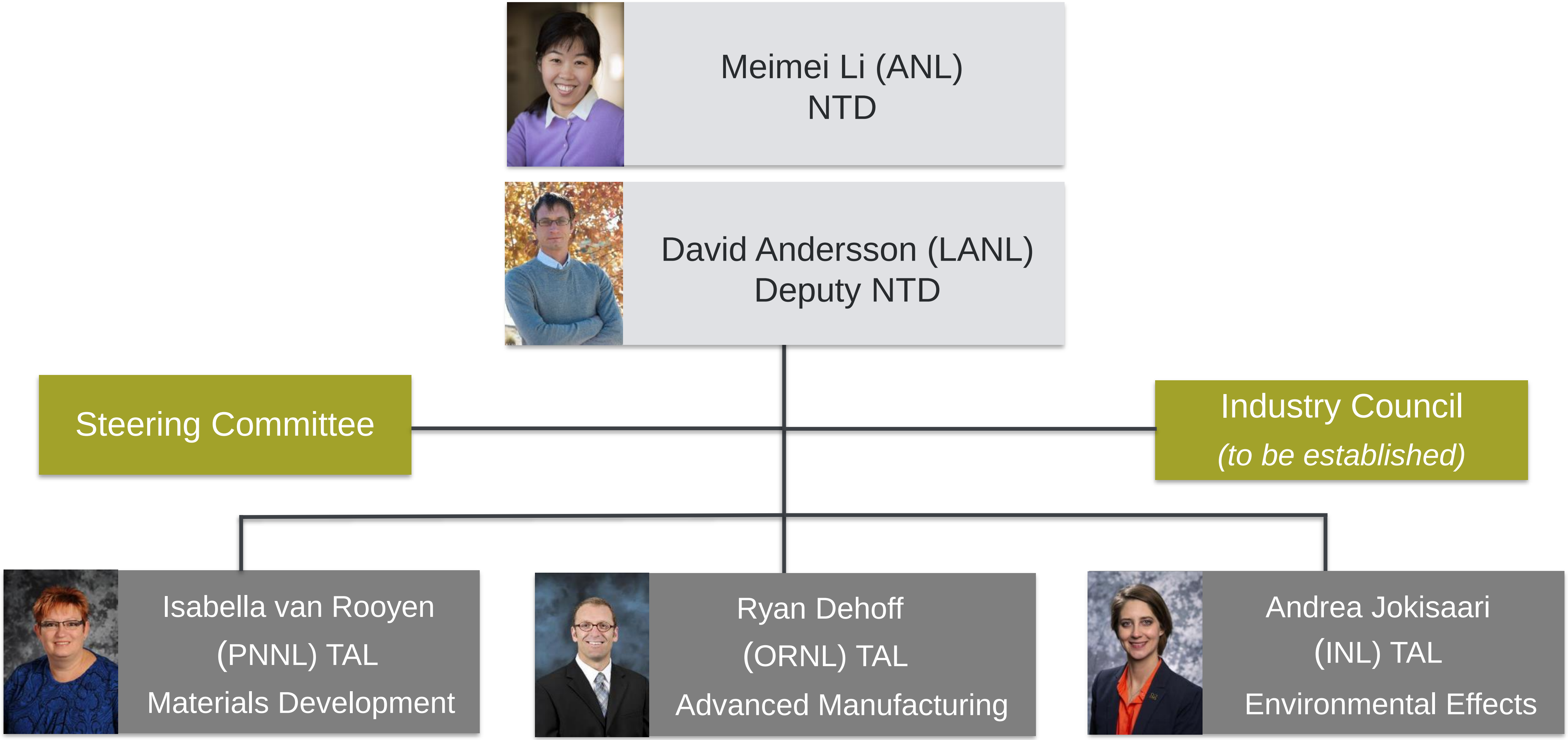
Advanced Materials & Manufacturing Technologies (AMMT) Program

May 18, 2022

Dirk Cairns-Gallimore, DOE Federal Manager

Meimei Li (ANL), NTD

AMMT Organizational Structure



Meimei Li (ANL)
NTD

David Andersson (LANL)
Deputy NTD

Steering Committee

Industry Council
(to be established)

Isabella van Rooyen
(PNNL) TAL
Materials Development

Ryan Dehoff
(ORNL) TAL
Advanced Manufacturing

Andrea Jokisaari
(INL) TAL
Environmental Effects

NTD: National Technical Director; TAL: Technical Area Lead

AMMT Mission, Vision and Goals

Mission

- To develop cross-cutting technologies in support of a broad range of nuclear reactor technologies.
- To maintain U.S. leadership in materials & manufacturing technologies for nuclear energy.

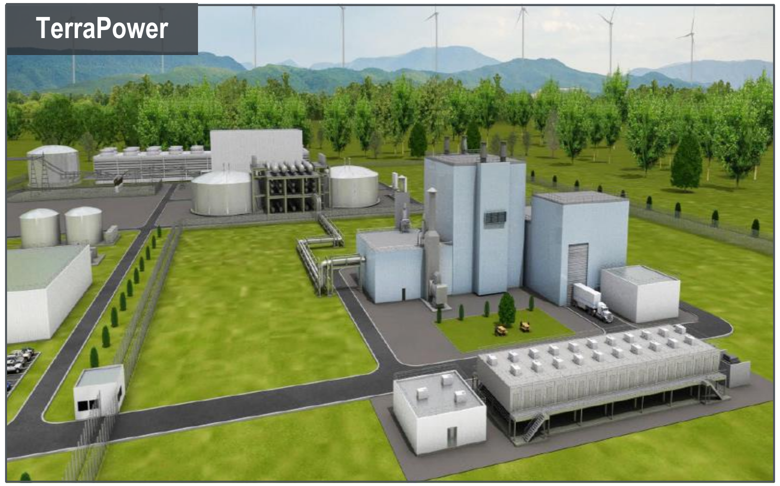
Vision

To accelerate the development, qualification, demonstration and deployment of advanced materials and manufacturing technologies to enable reliable and economical nuclear energy.

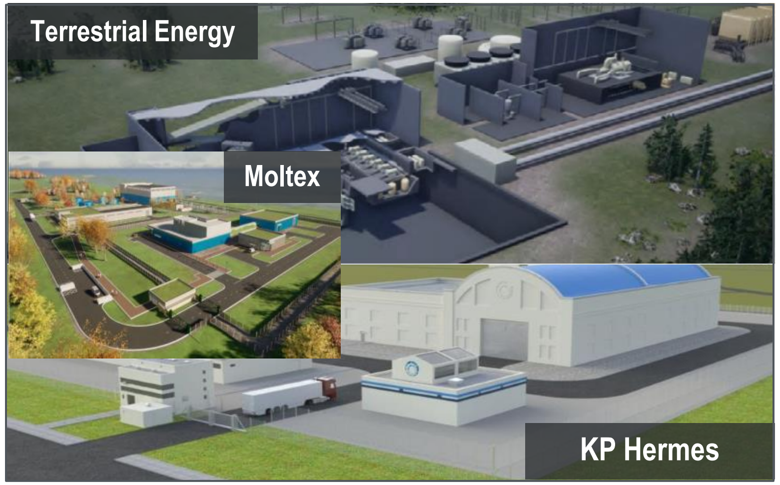
Goals

- To develop advanced materials & manufacturing technologies that have cross-reactor impacts.
- To establish a comprehensive framework for rapid qualification.
- Technology demonstration and deployment.

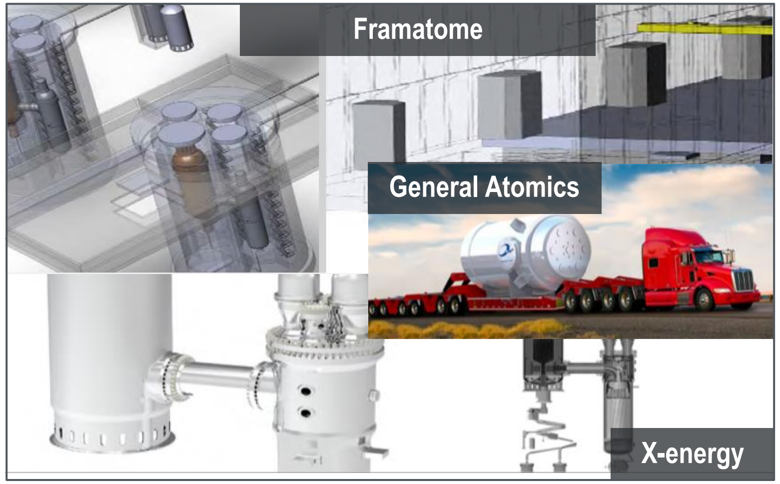
Nuclear Energy Technology Landscape



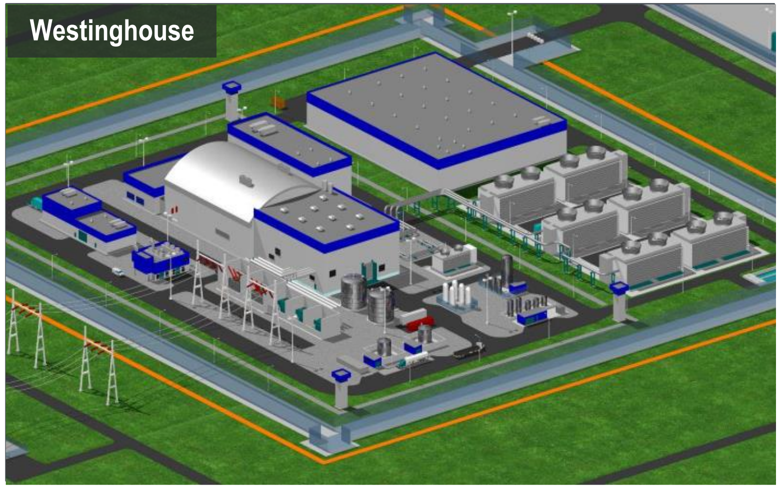
Sodium-cooled Fast Reactor (SFR)



Molten Salt Reactor (MSR)



High-temp Gas-cooled Reactor (HTGR)



Lead-cooled Fast Reactor (LFR)

Small Modular Reactor (SMR)

Micro-reactor

Nuclear Innovation Alliance (2021), "Advanced Nuclear Reactor Technology: a primer."

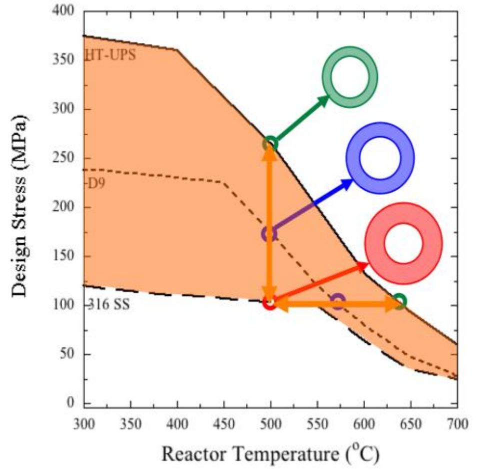
Material Needs: Pushing the Limits

Reactor Type	Coolant	Neutron spectrum	Operating temperature	Pressure	Candidate Materials	Material Challenges	Stakeholders
SFR	Na	Fast	500-550°C	Near atmospheric	G91, 316H, A709	Cost reduction, carburization/decarburization	Terrapower, GE, ARC
MSR	Fluoride or chloride salt	Thermal or fast	600-750°C	Near atmospheric	Graphite, ceramic composites; High-Ni, low-Cr alloys, steels	Radiation tolerance, high-temperature materials that are compatible with salts, actinides and fission products	Terrapower, Southern, Terrestrial, Elysium, Karios, Flibe, moltex
HTGR	He	Thermal or fast	≤850°C	7 MPa	Graphite, ceramics; A800H, A617, LAS, FM steels, 316H with cladding	Radiation-tolerant, high-T materials; graphite radiation testing; high-T material qualification	General atomics, X-energy, Framatome
LFR	Pb, Pb-Bi	Fast	480-550°C	Near atmospheric	Steels, coatings	Radiation-tolerant, high-T structural materials with coolant compatibility	Westinghouse
SMR /LWR	H_2O	Thermal	≤320°C	15 MPa	ASS, F/M, LAS, Ni alloys	Radiation tolerance, corrosion resistance	NuScale, GE,EPRI Westinghouse, Framatome, Holtec
Micro-reactor	He, Heat pipes	Thermal or fast	>750°C		Ceramic composites Steels, Ni alloys	Radiation-tolerant, high-T materials; graphite radiation; high-T material qualification	Westinghouse, BWXT, X-energy, Radiant, Oklo, USN

Advanced Materials & Manufacturing: Enabling Technology

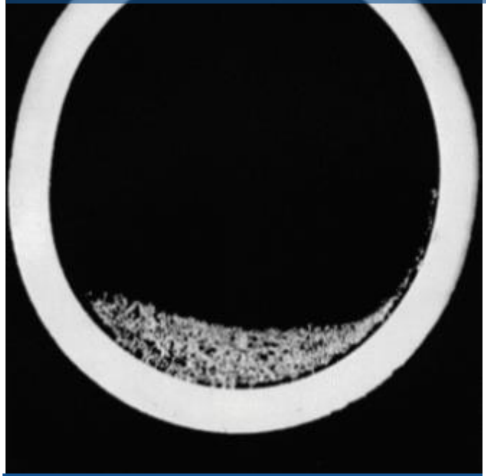
Industry Benefits

Heat Resistance



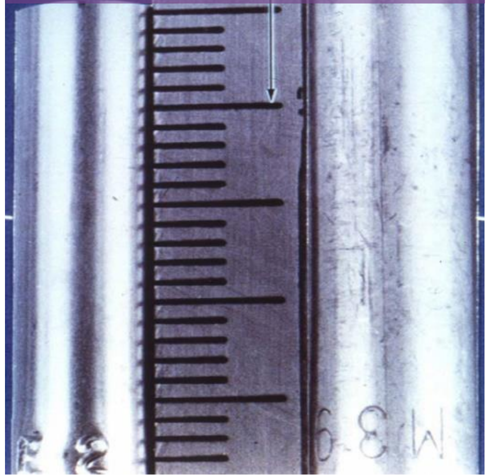
- Higher operating temperature
- Greater thermal efficiency
- Improved safety
- Cost reduction

Corrosion Resistance



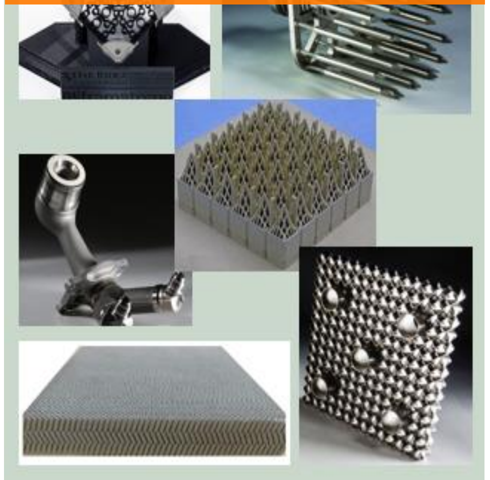
- Enable a wide range of reactor technologies
- Enable new reactor concepts
- Reduce maintenance cost

Radiation Resistance



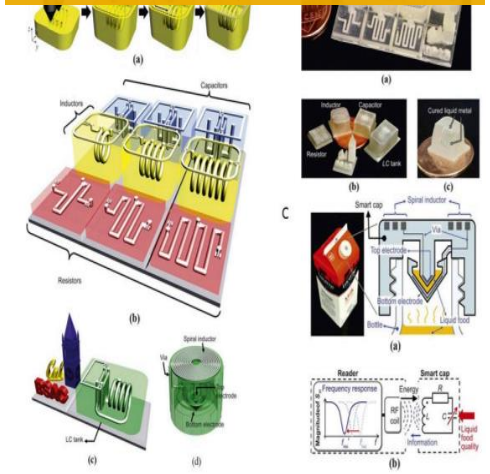
- Long lifetime
- Less inspection and maintenance cost
- Fewer component replacements

Innovative Design



- Performance enhancement
- Design flexibility
- Reduce supply chain
- Lower costs
- High-performance materials

Embedded Sensing



- Enhance system control
- Enable health monitoring
- Allow for autonomy

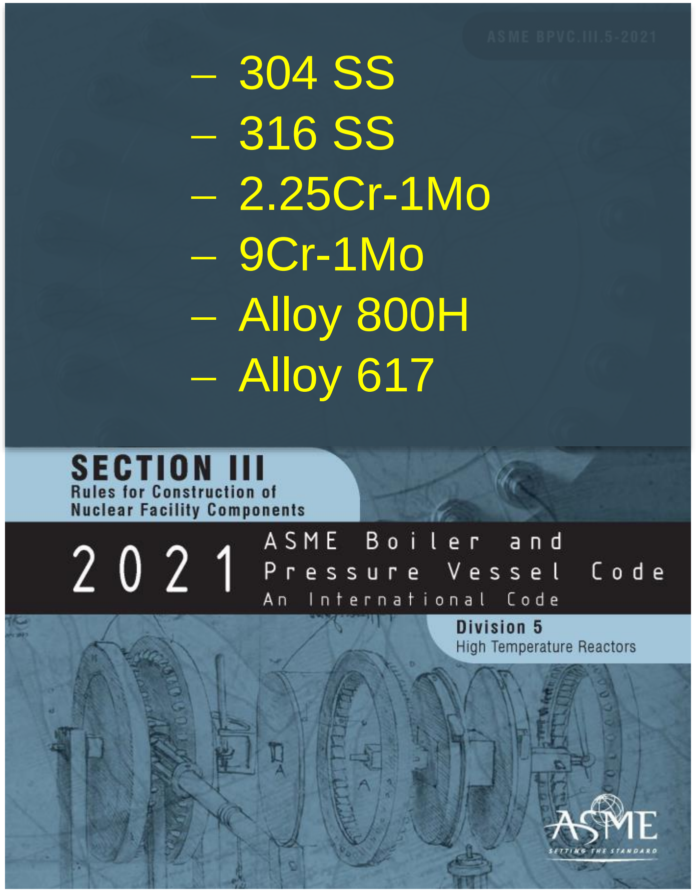
***Rapid qualification** will shorten the development cycle and time-to-market.*

J. Busby (unpublished); Molten Salt Chemistry Workshop (2017); Straalsund et al. JNM 108&109 (1982) 299.

Y. Xu et al, Sensors 17 (2017) 1166.

Our Challenge: Qualification of High-temperature Materials

Only **six materials** have been approved for nuclear construction at elevated temperatures in the ASME Code.



- 304 SS
- 316 SS
- 2.25Cr-1Mo
- 9Cr-1Mo
- Alloy 800H
- Alloy 617

ASME BPVC.III.5-2021

SECTION III
Rules for Construction of Nuclear Facility Components

2021 ASME Boiler and Pressure Vessel Code
An International Code

Division 5
High Temperature Reactors

ASME
SETTING THE STANDARD

Office of Nuclear Energy

New Alloy Material Approved for Use in High-Temperature Nuclear Plants

MAY 19, 2020

“Alloy 617 was added to the code in the fall of 2019 and is the first high-temperature material cleared for commercial use since the 1990s.”

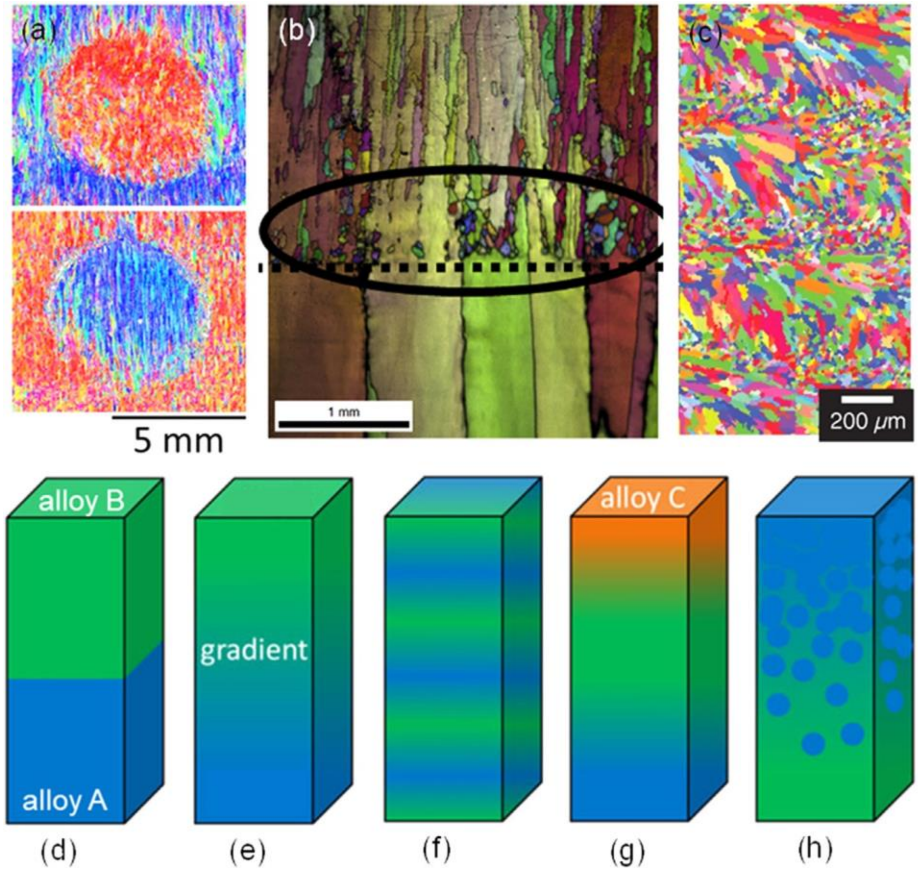
“**Getting a new material into the code is a lengthy process** and requires significant amounts of data. The national labs spent years testing the material properties of Alloy 617 in order to qualify the metal for commercial use.”

Current qualification approach relies on extensive testing and empirical modeling and limits the number of qualified materials.

Our Challenge: Qualification of AM Materials

Qualifying AM materials/components requires Paradigm Shift.

- Additive manufacturing is a domain-by-domain (e.g. point-by-point, line-by-line, and layer-by-layer) highly-localized process.
    - *High variability in AM materials*
    - *Multi-material components is voxel-based design with spatially varying microstructures and properties.*
- Materials and components are formed simultaneously vs. sequentially in conventional manufacturing.
- Digital manufacturing
    - *In situ sensing*
    - *In-process monitoring*
    - *Real-time decision making*
    - *Digital twins*
- Manufacturing technology development outpaces the qualification and licensing process, limiting their impact on nuclear reactor technologies.

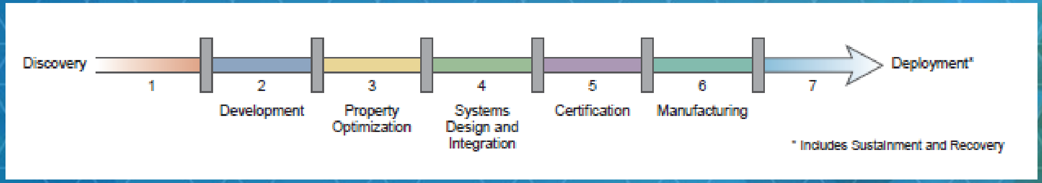


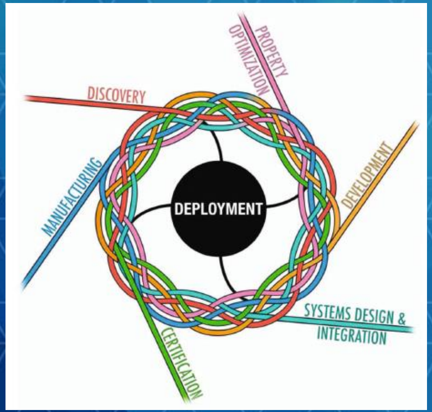
Site-specific microstructures of (a-c) single- and (d-h) multi-material alloy obtained by additive manufacturing.

Z. Liu, et al., J. Mater. Sci. & Tech. 100 (2022) 224.

Our Opportunity: Harness Materials Science Advances

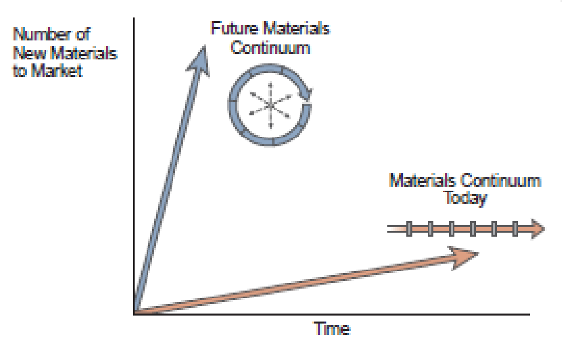
Materials Genome Initiative (MGI)





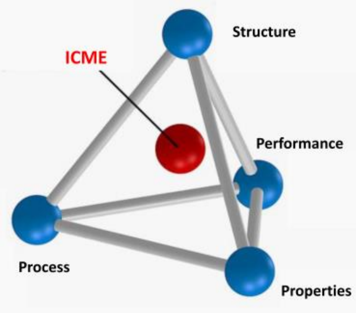
Path from material discovery to market

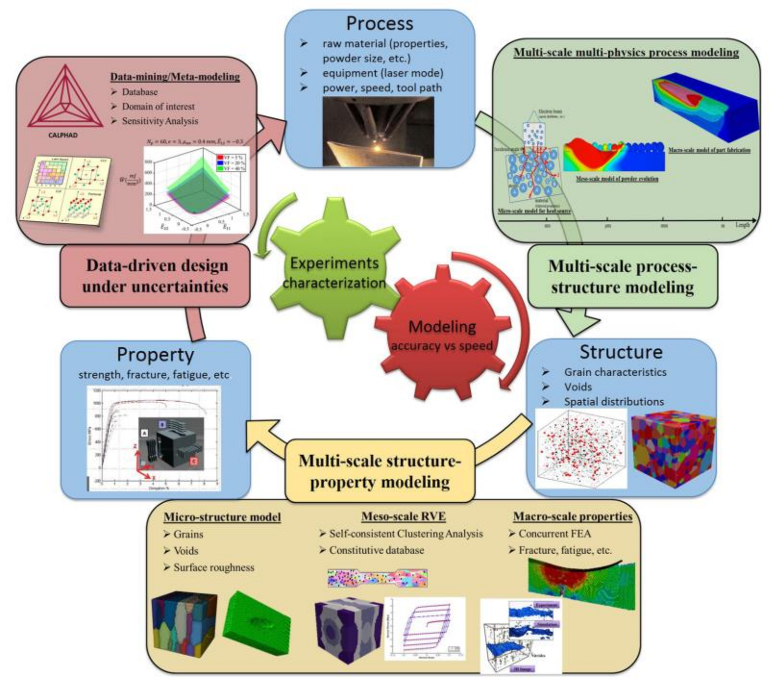
- Historically, a sequential process
- Today, it can happen concurrently and in a circular way
- Significantly shortens the materials development cycle



MGI for Global Competitiveness (2011);
MGI Strategic Plan (2021).

Integrated Computational Materials Engineering (ICME)



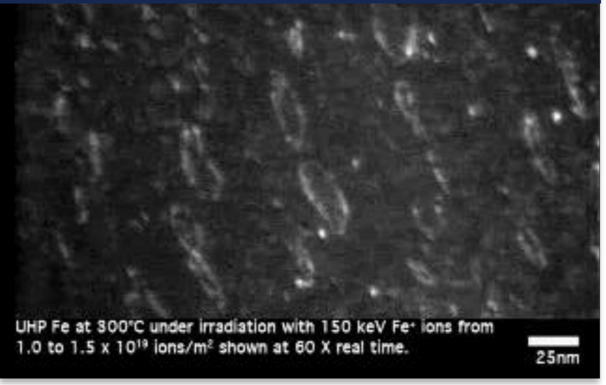


W. Yan, et al., Comput. Mech. 61 (2018) 521.

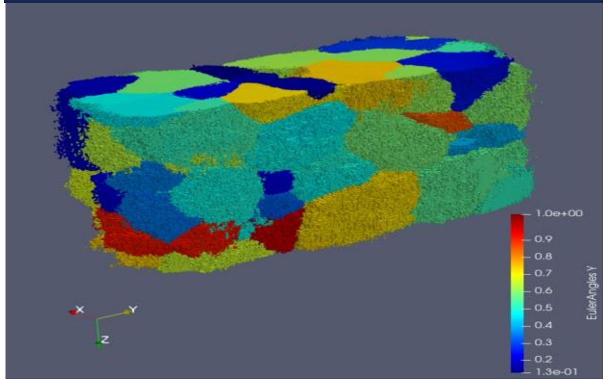
Our Opportunity: Advanced Experimental & Computational Tools

Advanced Characterization

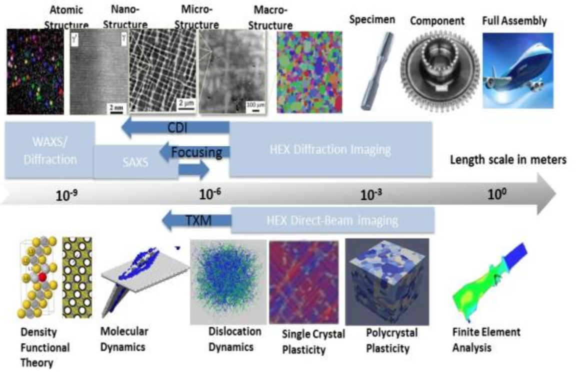
Real-time Characterization



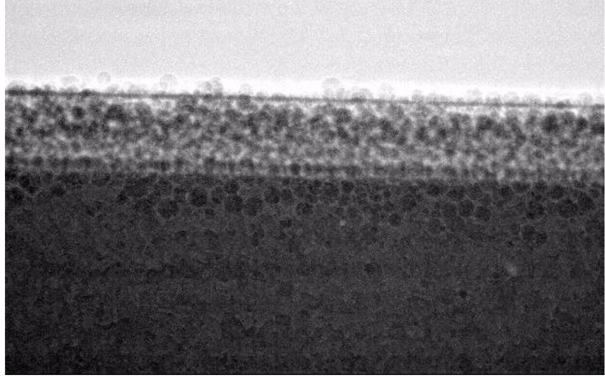
Non-destructive 3D characterization



Multiscale Characterization

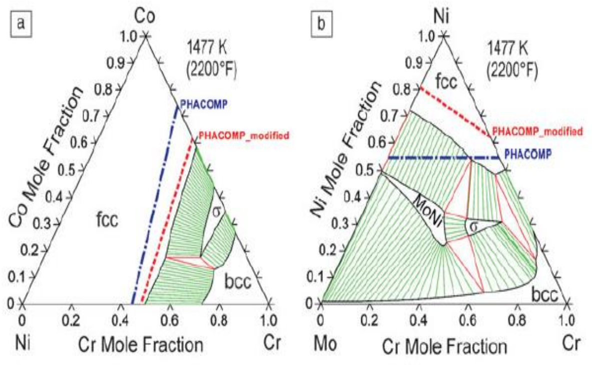


In-situ Experiment



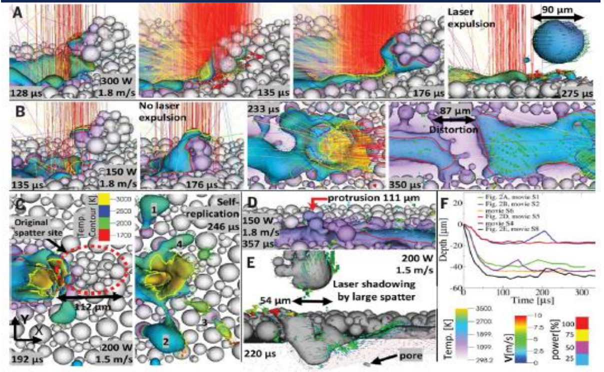
Modeling/Simulation and ML/AI

Computational Material Design



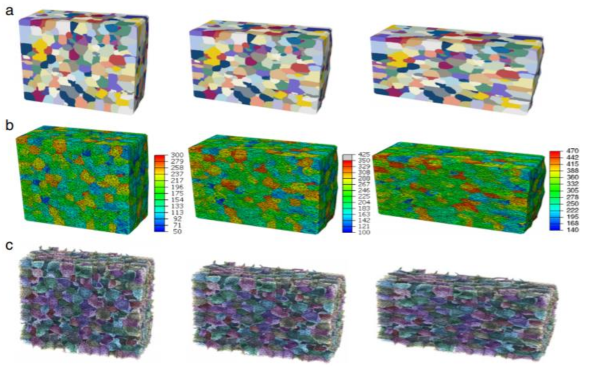
M. Knezevic et al. Comput. Meth. Appl. Mech. Eng. 277 (2014) 239

Metal additive manufacturing process simulation



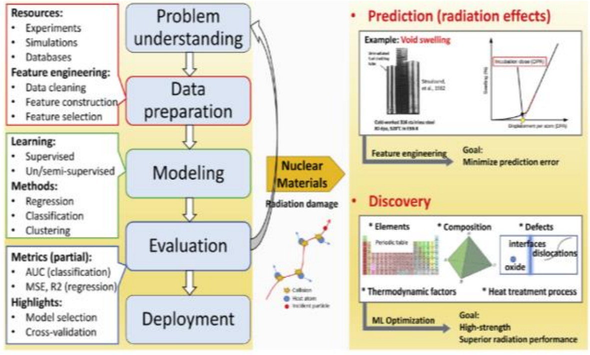
M. Jin et al., JNM 523 (2019) 189.

3D crystal plasticity modeling of deformed microstructure



Khairallah et al, Science 368 (2020) 660.

Predicting void swelling with machine learning



Resources:
- Experiments
- Simulations
- Databases

Feature engineering:
- Data cleaning
- Feature construction
- Feature selection

Learning:
- Supervised
- Un/semi-supervised

Methods:
- Regression
- Classification
- Clustering

Metrics (partial):
- AUC (classification)
- MSE, R2 (regression)

Highlights:
- Model selection
- Cross-validation

- Prediction (radiation effects)

Goal: Minimize prediction error

- Discovery

Goal: High-strength Superior radiation performance

W. Xiong et al, MRS Bulletin (2015).

AMMT Program Strategy

1. Target big challenges and game-changing technologies with the focus on demonstration.

2. Perform transformative research to develop new materials concepts and design.

3. Develop a broad range of materials and manufacturing technologies that have cross-reactor impacts.

4. Accelerate qualification by integrating materials development, advanced manufacturing, and environmental effects.

5. Combine computational, experimental tools, and digital data for design of materials and components through the product lifecycle.

6. Execute R&D in multidisciplinary and cross-organizational teams to leverage collaboration and integration.

7. Engage with all stakeholders to understand their foundational needs for industry, standards, code bodies, and regulators.

8. Demonstrate and deploy technologies with commercial stakeholders to enable technology adoption by the nuclear industry.

AMMT Program Elements

Development, Qualification & Demonstration

Target big challenges and game-changing technologies with the focus on demonstration

- Develop advanced materials & manufacturing technologies and perform rapid evaluation of environmental effects
- Establish a rapid qualification framework
- Technology demonstration and deployment

Capability Development & Transformative Research

Focus on materials innovations including developing infrastructure in support of innovations as well as development, qualification and demonstration

- Develop high-throughput, accelerated testing and characterization techniques
- Develop modeling capabilities for materials design, development and qualification
- Perform transformative research to develop new material concepts and design

Collaborative Research & Development

Working with other DOE programs, NRC, industry, Universities, etc.

- Investigate a broad range of advanced materials and manufacturing technologies
- Address reactor-specific issues
- Provide near-term material solutions to nuclear industry

Advanced Materials & Manufacturing Development

Objectives

- Integrated development of advanced materials and advanced manufacturing (AM)
- Application-based materials design and development integrating functional requirements, characterization, manufacturing data and modeling.
- Rapid evaluation of environmental effects including high-temperature, radiation and corrosion performance.

Topics

- AM-based or AM-optimized new materials for nuclear applications
- Innovative materials with microstructure & microchemistry engineering
- Advanced manufacturing (AM) of existing reactor materials
- Advanced manufacturing (AM) of innovative new materials
- AM component design optimization by integrating process-structure-property-performance relationship into Design-for-Functions tools
- Multi-attribute optimization: balance/trade-offs between different properties and functional requirements
- Multifunctional, multi-material component designs and fabrication
- Design of embedded sensor for reactor in-service monitoring

Materials Development

Focus on **AM Materials** – materials that can be optimized/improved by advanced manufacturing or new materials enabled by advanced manufacturing (AM).

Improve/optimize existing reactor materials

- Develop optimized AM 316 SS to minimize microstructural heterogeneity with combined composition modification and manufacturing process.
- Modify existing material classes (e.g. 316 SS, G91, Ni alloys) with composition modification and manufacturing process to improve radiation, corrosion, and heat resistance.

Develop new reactor materials

- Develop corrosion-resistant cladding/coatings on structural material substrates.
- Design new materials specifically for advanced manufacturing, e.g. metal/ceramic composites, refractory alloys, functionally graded materials

Critical minerals

- Critical material waste minimization of non-uranium significant materials.
- Develop a supply solution through application of replacement material design and development enabled by advanced manufacturing.

Advanced Manufacturing Technologies

The Nuclear Energy Institute (NEI) identified 16 advanced manufacturing methods that are of the most interest to fabricate components for nuclear power plants. The US NRC is currently evaluating five advanced manufacturing technologies:

New Technologies

Additive Manufacturing

- Laser powder bed fusion (L-PBF)
- Directed energy deposition (DED)

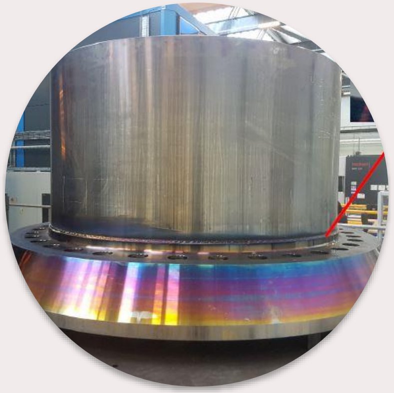
"Mature" Technologies

- Powder metallurgy hot isostatic pressing (PM-HIP)
- Electron beam welding (EBW)
- Cold spray.

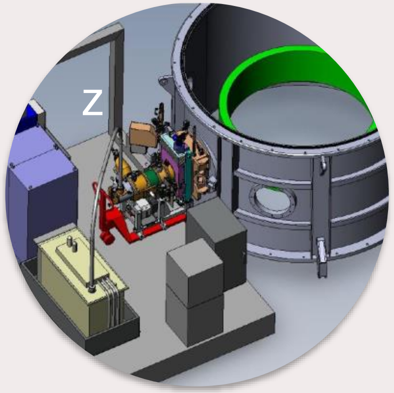
PM-HIP and EBW are being developed and demonstrated by nuclear industry working with DOE-NE.

DOE-NE Funded EPRI Projects

SMR
PM-HIP



SMR
EBW



Modular
in-chamber
EBW

Additive Manufacturing

Advance understanding

- Manufacturing processes
- Manufacturing technologies

In-process Monitoring

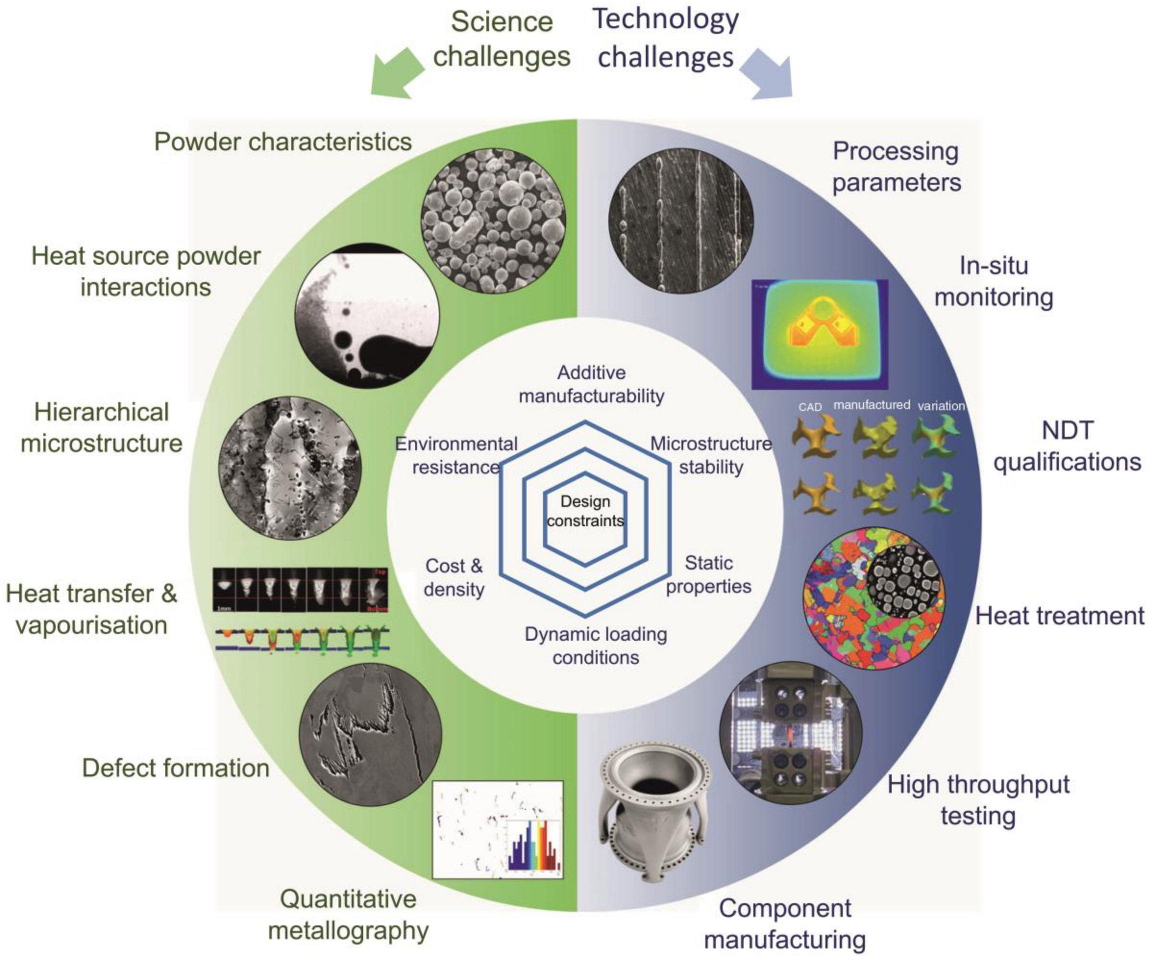
- Process sensing and monitoring
- Computer vision inspection

Post-process NDE

- High-resolution NDE techniques
- Defect acceptance criteria

Materials Manufacturing

- Existing reactor materials (e.g. 316 SS)
- Metal/ceramic composites
- Refractory alloys
- Multi-material functional gradients



"Fundamental understanding of the processing science includes powder flowability and powder shape distribution, interaction with heat source, hierarchical microstructure formed, defects mitigation and better quantification of metallurgical features. Challenges on the technology perspective includes parametric optimization of processing, real-time monitoring, establishment of qualification standard, high throughput testing and manufacturing of scaled-up components."

C. Panwisawas, et al. Nature Communications (2020)

Environmental Effects

Irradiation Effect

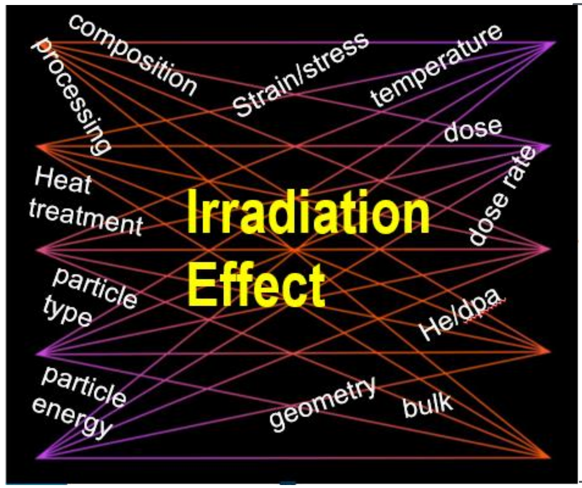
- Rapid evaluation using ion irradiation
- Neutron irradiation database
- Regulatory acceptance of combined ion & neutron irradiation results

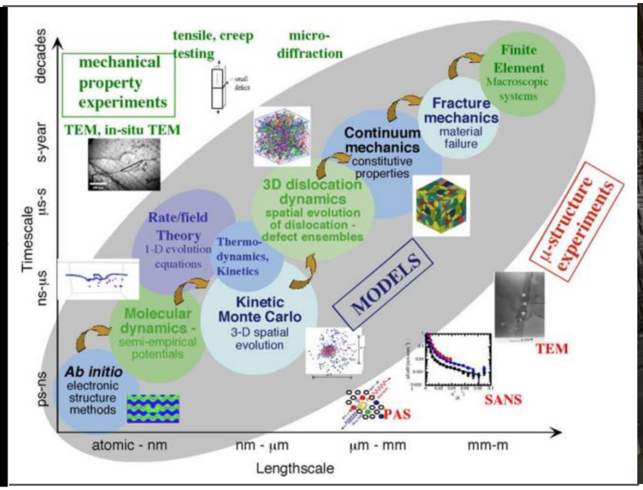
Material Compatibility

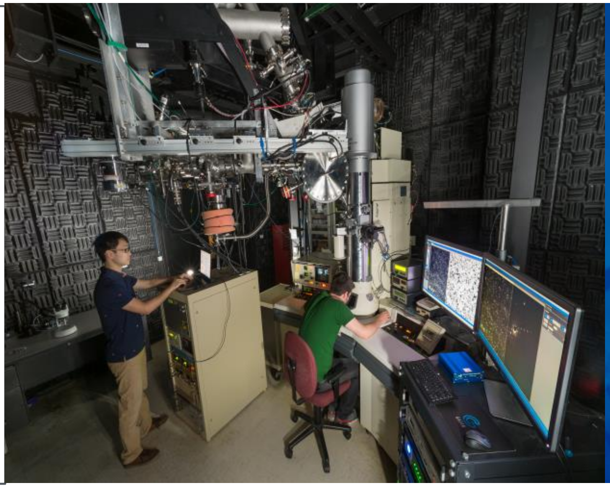
- Understand and predict the effect of corrosion process on microstructure and properties

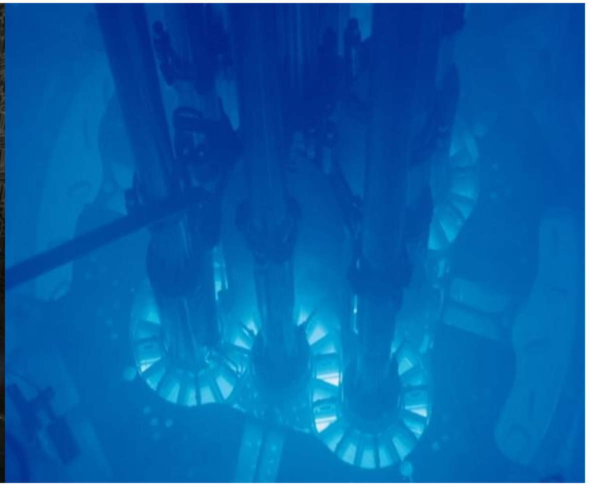
High-temperature Effect

- Short-term creep and creep-fatigue testing
- Long-term creep and creep-fatigue property prediction









B.D. Wirth et al., JNM 329 (2004) 103.

Rapid Qualification

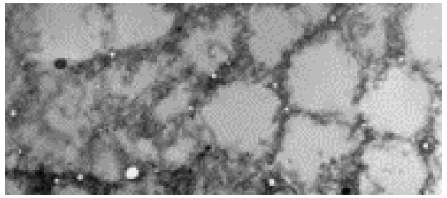
Develop Process-Structure-Property-Performance based Qualification

To address the challenges posed by advanced manufacturing that cannot be easily handled by traditional qualification approaches, we will take this opportunity to develop an accelerated qualification framework by integrating materials development, advanced manufacturing, environmental effects.

.

Use integrated experimental, computation and data-driven tools

The new qualification framework will capitalize on the wealth of digital manufacturing data, integrated computational materials engineering (ICME) and machine learning/artificial intelligence (ML/AI) tools, and accelerated, high-throughput testing and characterization techniques.



Establish new qualification framework through qualifying AM 316 SS

Additively-manufactured 316 stainless steel (AM 316 SS) will serve as a case study for the development of a new qualification framework.

Ensure new qualification framework applicable to other materials systems

Develop an agnostic qualification approach applicable to a variety of material systems, e.g. metallic, ceramic and composites, as well as a variety of advanced manufacturing techniques.

Selection of AM 316 SS: Material Scorecards

Background

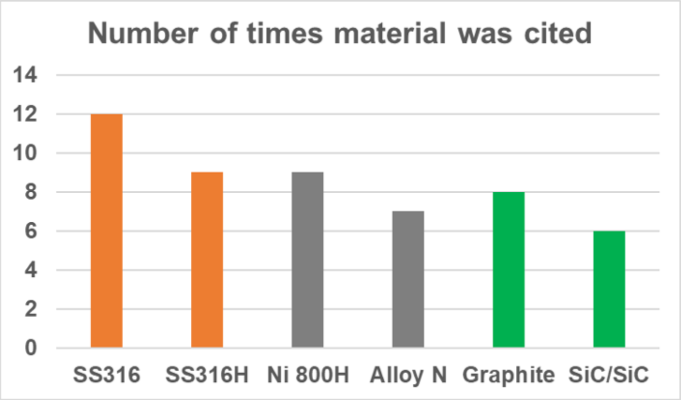
- Developed preliminary material scorecards to prioritize for advanced manufacturing.
- Guided by evaluation criteria established by the program.
- Scorecards based on stakeholder input and literature.
- Considered seven reactor types: LWR, SFR, LFR, MSR, VHTR, Micro-reactor.

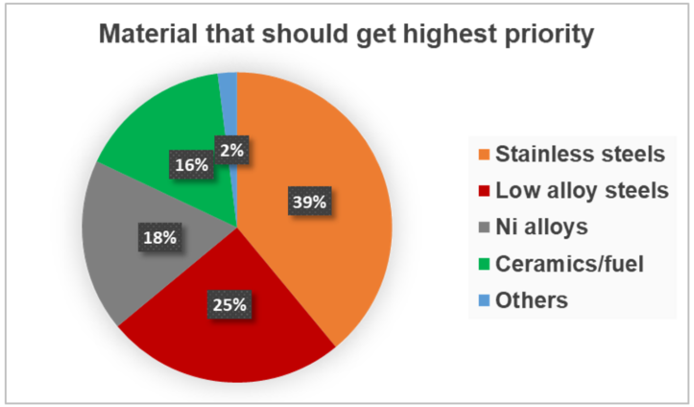
Conclusions

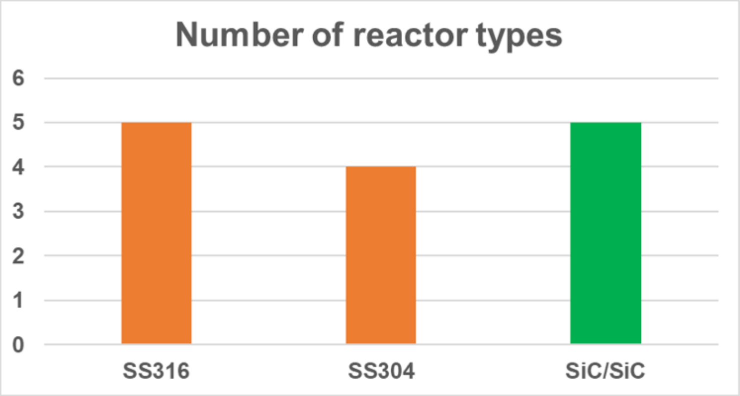
- Austenitic stainless steels (304 and 316) are favored for several reactor types.
- HT-9, Inconel 617, and low-alloy steels SA508, SA533 also had high scores.

Evaluation Criteria for Scorecards

1. Code Availability
2. Minimal Gaps in Data Availability for Performance Values and Measurements
3. Technical Maturity for End Use/Development Stage (Design, Materials, Components, etc.)
4. Deployment readiness requirements (near-term, mid-term, long-term)
5. Supply Chain Availability
6. Programmatic factors/Cross-reactor applications







Technical Basis For Regulatory Acceptance of AM 316 SS

Process Understanding

- Understand the effects of variations in powder composition and characteristics on AM 316 SS microstructure
- Understand the effects of processing and post-processing conditions on residual stress, porosity and microstructure of AM 316 SS.
- Understand the effects of component geometry on part quality and print consistency including geometric accuracy, defects, surface finish, residual stress, and location- and orientation-dependence of microstructure and properties.
- Understand machine-to-machine variability and repeatability.
- Generate baseline mechanical property data of as-built and post-treated materials for model validation & verification and determine performance limits to support the ASME Code Case.
- Modeling the correlation of mechanical properties with microstructural and material processing parameters with uncertainty quantification.

In-process Monitoring

- Develop integrated in-process sensing, monitoring, and control technologies with the considerations of cost, machine compatibility and workflow (e.g. optical and thermal imaging, spectroscopy, and in-situ NDE techniques).
- Demonstrate in situ detection of processing anomalies (dimension, surface finish, density, hot spots, defects) and develop the correlation of in-situ process data with measured mechanical properties
- Demonstrate how in situ processing data can be used to complement/guide post-process NDE.
- Determine what in-process monitoring data is needed for verification and validation of the part for nuclear applications.
- Develop a pathway that will allow use of in-situ processing data records for nuclear component qualification and certification.

Post-process NDE

- Develop a technical basis by intentionally generating defects in mechanical testing specimens and determining what types/sizes/distributions of defects should be concerned for mechanical performance in reactor environments.
- Establish defect acceptance criteria of printed components to meet performance requirements.
- Identify/develop advanced reliable and high-resolution NDE techniques for non-destructive evaluation of parts with complex geometry.

Environmental Effects

- Understand the effects of composition and microstructure on irradiation behavior, e.g. irradiation creep, swelling, high-temperature He embrittlement and microstructural stability of AM 316 SS.
- Develop database of microstructure and mechanical properties of irradiated AM 316 SS.
- Model radiation responses based on the microstructure of AM 316 to account for microstructural variations under different processing and post-processing conditions.
- Understand environmental effects including SCC/IASCC for LWR applications and other corrosion mechanisms in advanced reactors.
- Demonstrate acceptable performance in irradiation environments of AM 316 using experimental data and modeling results.

NRC documents: ML21074A037, ML21074A040

Qualification: Phased Approach

Take a phased approach –

Transition from statistically-based qualification to equivalence-based qualification to eventual model-based qualification.

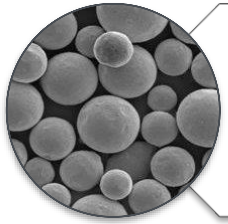
Statistically-based qualification based in extensive testing and empirical modeling

Equivalence-based qualification through testing to demonstrate a new material or process is equivalent to a previously qualified material or process

Model-based qualification where performance of a material or process is demonstrated through modeling and verified with minimal testing.

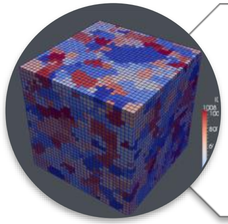
ASME Code Cases for AM 316 SS

Develop Code cases for laser powder bed fusion (LPBF) 316 SS to be included in the ASME Code Section III Division 5 (including rules for both low-temperature and elevated-temperature services).

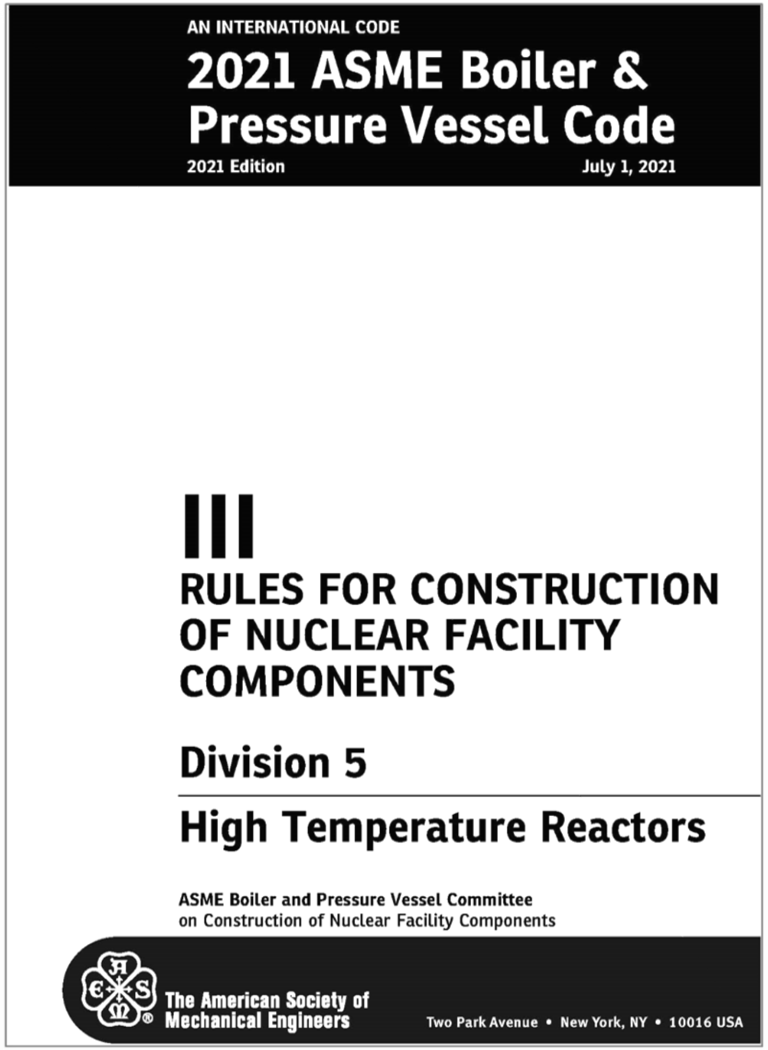


Develop ASME material specifications, including the reuse of recycled powder for nuclear applications.

Establish AM 316 SS property handbook including tensile, creep and creep-fatigue, and thermal aging data for high-temperature operating environments.



Model high-temperature mechanical properties of AM 316 SS with uncertainty quantification.



AN INTERNATIONAL CODE

2021 ASME Boiler & Pressure Vessel Code

2021 Edition July 1, 2021

III

RULES FOR CONSTRUCTION OF NUCLEAR FACILITY COMPONENTS

Division 5

High Temperature Reactors

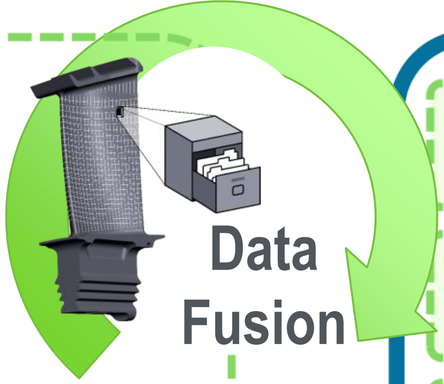
ASME Boiler and Pressure Vessel Committee
on Construction of Nuclear Facility Components

The American Society of Mechanical Engineers
Two Park Avenue • New York, NY • 10016 USA

Multi-Dimensional Data Correlation (MDDC) Platform

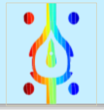
Digital Twin

Spatially Tracked Data



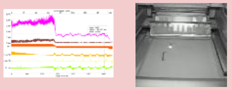
Manufacturing

Process Parameters



Feedstock Information

In-Situ Data



Post Processing

Characterization

Material Characterization

Non-Destructive Testing

Destructive Testing

Lifetime & Performance

MDDC

Twin 1

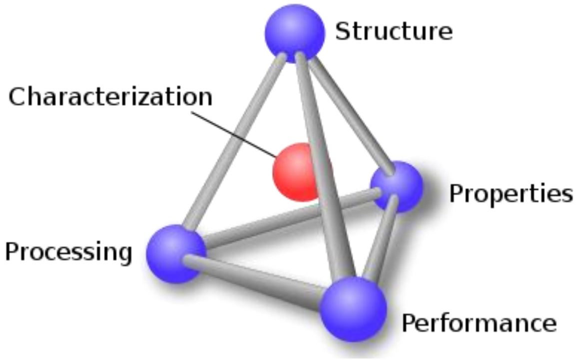
Twin 2

Twin …

Twin n

Toolkit

- Artificial Intelligence
- Machine Learning
- Data Analytics
- Process Models
- Materials Models
- Performance Models

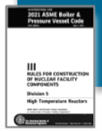


Digital Twins and MDDC Toolkit Accelerates Development

Demonstrations

3 years

Digitally Aided Qualification



2021 ASME Boiler & Pressure Vessel Code

III

RULES FOR CONSTRUCTION OF NUCLEAR FACILITY COMPONENTS

Division 5

High Temperature Reactors

5 years

AI Based Design

10 years

Improve Performance, Reliability and lifetime of Nuclear Components

Technology Demonstration and Deployment

Objectives

- To provide a test of technical performance under representative operating environments and further investigate economical and regulatory feasibility.
- To demonstrate experimental and computational tools and frameworks assisting materials development and qualification.

Component Selection

Identify specific reactor components that could take advantage of new materials or AM technologies for demonstration.

Regulatory Acceptance

Outline levels of risks associated with demonstration: from low-risk to high-risk.

Supply Chain

Identify potential nuclear vendors, powder supplies, vendor qualification, NQA-1 certification.

Digital Twin

Develop a digital twin framework and demonstration of digital twin-enabled novel control mechanisms.

Stakeholder Interaction

Close interactions with advanced reactor campaigns, NRIC, NRC, reactor developers and vendors, and non-nuclear commercial partners.

Knowledge Transfer

Transfer knowledge and experience to industry vendors, supply chain, owners.

AMMT Program Element: Capability Development & Transformative Research

Development, Qualification & Demonstration

Target big challenges and game-changing technologies with the focus on demonstration

- Develop advanced materials & manufacturing technologies and perform rapid evaluation of environmental effects
- Establish a rapid qualification framework
- Technology demonstration and deployment

Capability Development & Transformative Research

Focus on materials innovations including developing infrastructure in support of innovations as well as development, qualification and demonstration

- Develop high-throughput, accelerated testing and characterization techniques
- Develop modeling capabilities for materials design, development and qualification
- Perform transformative research to develop new material concepts and design

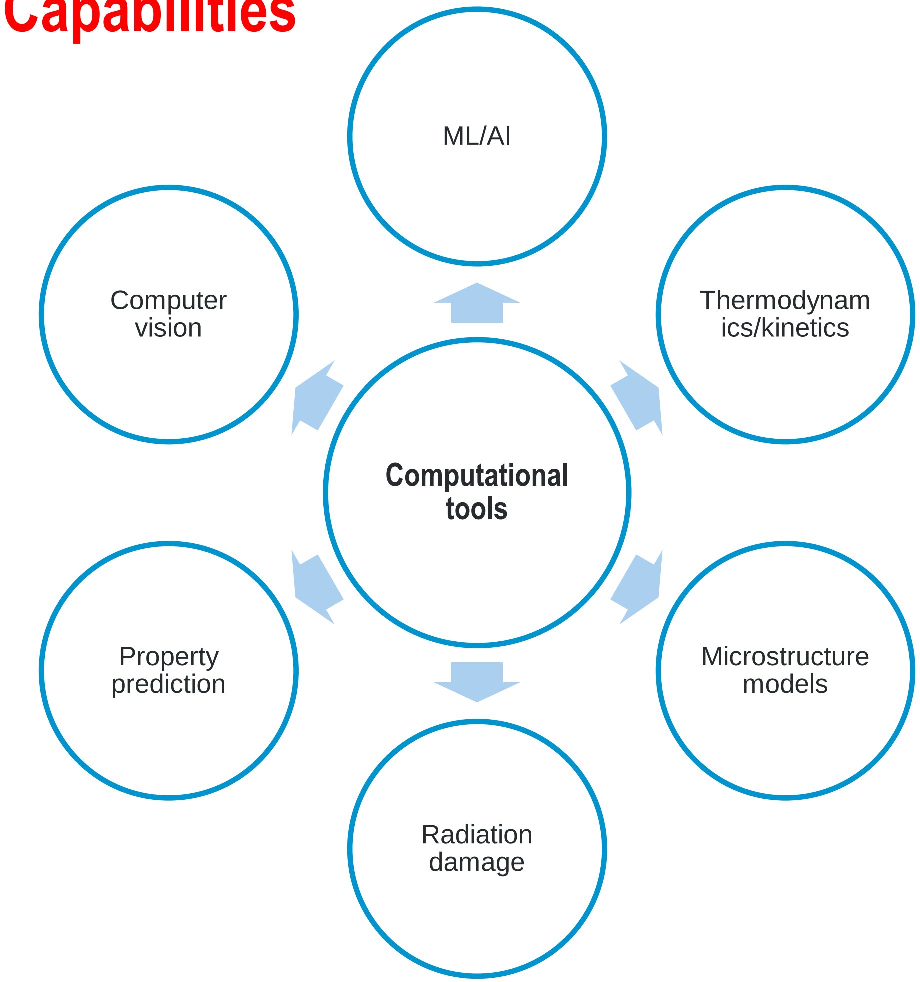
Collaborative Research & Development

Working with other DOE programs, NRC, industry, Universities, etc.

- Investigate a broad range of advanced materials and manufacturing technologies
- Address reactor-specific issues
- Provide near-term material solutions to nuclear industry

Experimental & Computational Capabilities

Computational Capabilities



Computational tools

ML/AI

Thermodynamics/kinetics

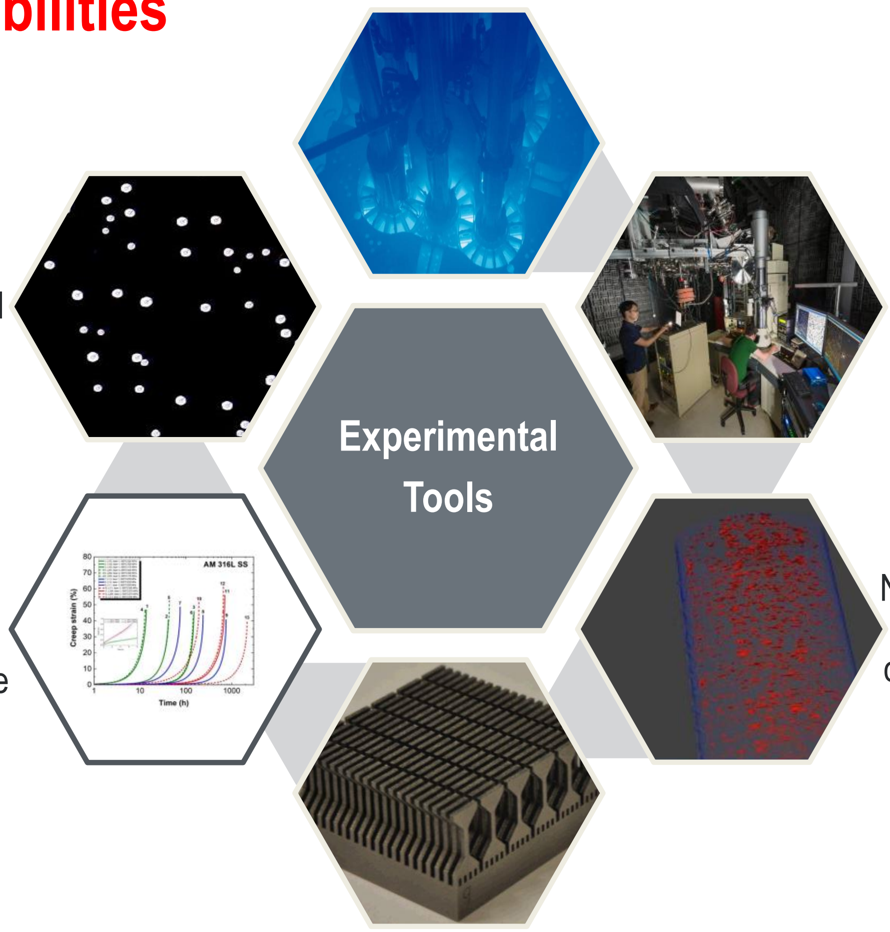
Microstructure models

Radiation damage

Property prediction

Computer vision

Experimental Capabilities



Advanced neutron irradiation platform

Accelerated characterization of environmental effects

Non-destructive, 3D advanced characterization

High-throughput subsize specimen testing & validation

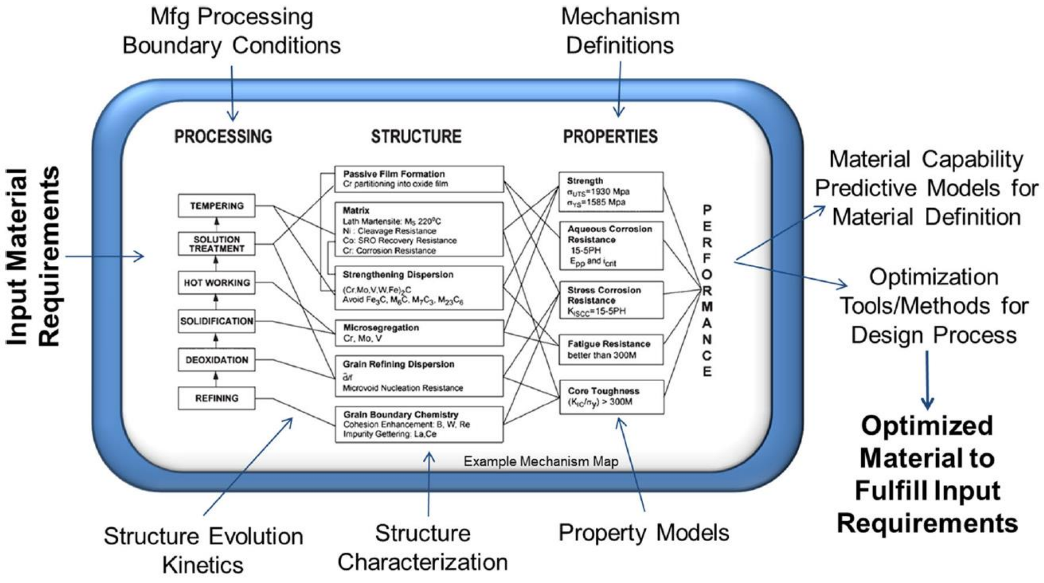
Accelerated creep and creep-fatigue testing

Automated microstructural analysis & quantification

New Material Concepts and Design

Develop materials from fundamental properties

- Leverage material design capabilities developed within the AMMT program and by other research for non-nuclear materials (such as MGI and ICME) with a new focus on advanced reactor considerations, especially irradiation effects.
- Enable modification of existing material classes to improve radiation, corrosion, and heat resistance.
- Design new materials for their service conditions to maximize their lifetime and avoid catastrophic failure mechanisms.
  - Define performance metrics and select alloy composition
  - Optimize microstructure with respect to irradiation performance and mechanical properties
  - Experimental validation of designed materials
  - Multi-attribute optimization
- Establish an agnostic material design and development integrated process



Each material class will have specific mechanisms and models

D. Furreret al., Integr Mater Manuf Innov 6(2017) 249.

AMMT Program Element: Collaborative R&D

Development, Qualification & Demonstration

Target big challenges and game-changing technologies with the focus on demonstration

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Collaborative Research and Development

Working with other DOE programs and organizations

Advanced Reactor Technologies
Code qualification/extension of structural alloys

Advanced Reactors Regulatory Development
Develop & demonstrate corrosion-resistant materials

Light Water Reactor Sustainability
Advanced manufacturing and demonstration

Nuclear Energy Advanced Modeling & Simulation
Computational tool

Nuclear Science User Facilities
Irradiation and advanced characterization

National Reactor Innovation Center
Technology demonstration and deployment

Advanced Sensors and Instrumentation
Embedded sensors

Fuel Cycle R&D
Accelerated irradiation

Nuclear Energy University Program
Universities

Advanced Manufacturing Office
Advanced manufacturing technology development & demonstration

Office of Science
Fundamental materials and manufacturing science

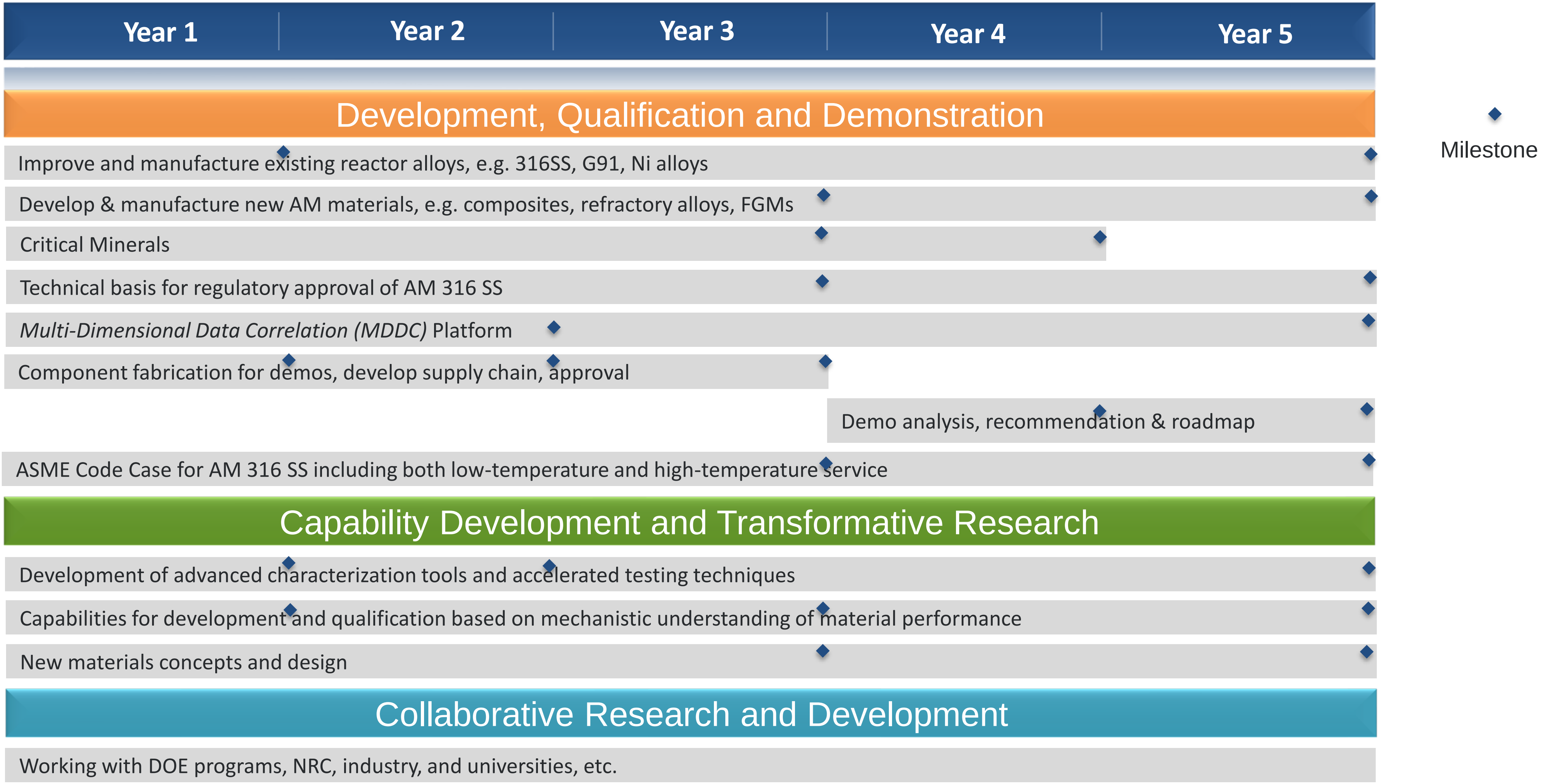
NRC
Regulatory acceptance

NIST, ASME, ASTM
Codes and Standards

Industry
Technology demonstration and deployment

NASA/DOD/others
Advanced Manufacturing

AMMT Five-Year Roadmap



Year 1 | Year 2 | Year 3 | Year 4 | Year 5

◆ Milestone

Development, Qualification and Demonstration

- Improve and manufacture existing reactor alloys, e.g. 316SS, G91, Ni alloys
- Develop & manufacture new AM materials, e.g. composites, refractory alloys, FGMs
- Critical Minerals
- Technical basis for regulatory approval of AM 316 SS
- *Multi-Dimensional Data Correlation (MDDC)* Platform
- Component fabrication for demos, develop supply chain, approval
- Demo analysis, recommendation & roadmap
- ASME Code Case for AM 316 SS including both low-temperature and high-temperature service

Capability Development and Transformative Research

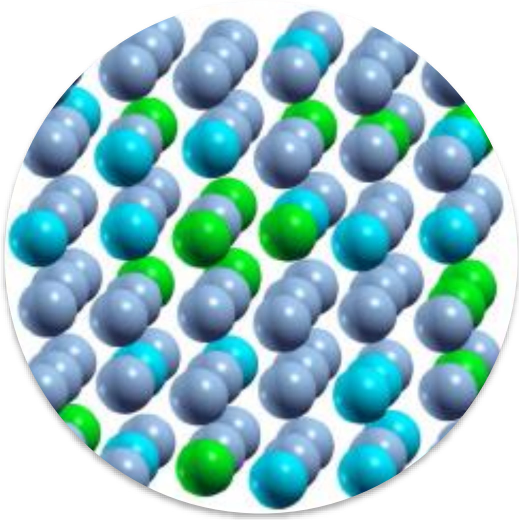
- Development of advanced characterization tools and accelerated testing techniques
- Capabilities for development and qualification based on mechanistic understanding of material performance
- New materials concepts and design

Collaborative Research and Development

- Working with DOE programs, NRC, industry, and universities, etc.

AMMT Core Technical Areas

AMMT has three inter-connected core technical areas:



Materials Development

↔

Advanced Manufacturing

↔

Environmental Effects

Program Integration

Development

- Materials Development: Design AM-based or AM-optimized materials
- Advanced Manufacturing (AM): Understand and optimize manufacturing process
- Environmental Effects: Perform evaluation of environmental effects

Qualification

- Materials Development: *Structure-Property* relationship
- Advanced Manufacturing: *Processing-Structure-Property* relationship
- Environmental Effects: *Processing-Structure-Property-Performance* relationship

Demonstration

- Materials Development: Design and qualify materials for targeted demonstration
- Advanced Manufacturing: Optimize and qualify manufacturing process for demonstration
- Environmental Effects: Qualify environment effects and provide demonstration design support

AMMT Program Summary

Development, Qualification and Demonstration

- Develop advanced materials & manufacturing technologies and perform rapid evaluation of environmental effects
- Establish a rapid qualification framework
- Technology demonstration and deployment

Capability Development & Transformative Research

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Collaborative Research and Development

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