U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NRC Activities in Advanced Manufacturing Technologies

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LWRS Spring Meeting

April 29-30, 2025

Advanced Manufacturing Technologies

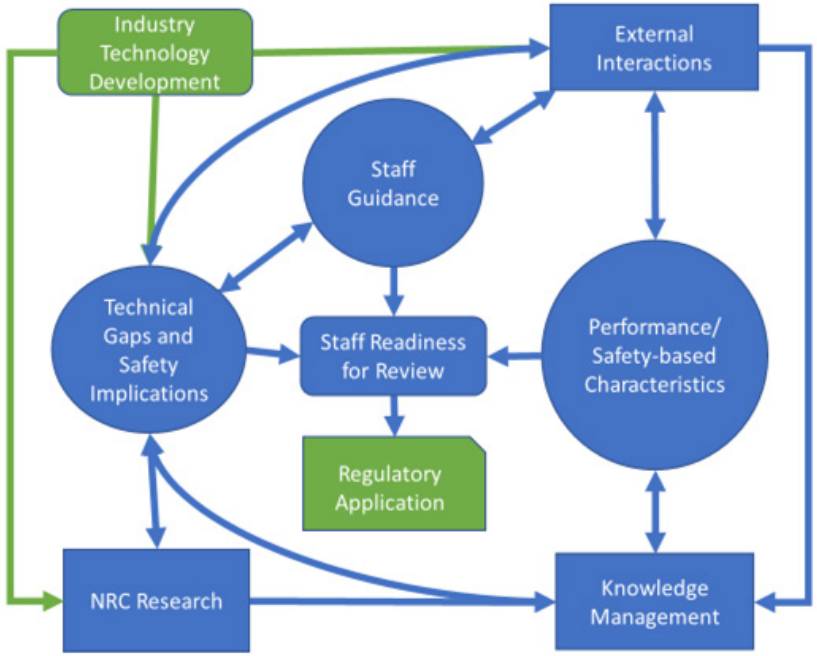
- Techniques and material processing methods that have **not** been:
  - Traditionally used in the U.S. nuclear industry
  - Formally standardized/codified by the nuclear industry
- **NRC Goal**: To proactively prepare staff for efficient, effective, and transparent regulatory review of AMT submissions

Initial focus areas

- Laser Powder Bed Fusion (LPBF)
- Laser Direct Energy Deposition (L-DED)
- Cold Spray (CS)
- Electron Beam Welding (EBW)
- Power Metallurgy—Hot Isostatic Pressing (PM-HIP)

Action Plan – Rev. 1, June 2020 –Sept 2022

- Task 1 - Technical Preparedness
  - Technical information, knowledge and tools to prepare NRC staff to review AMT applications
- Task 2 - Regulatory Preparedness
  - Regulatory guidance and tools to prepare staff for efficient and effective review of AMT-fabricated components
- Task 3 - Communications and Knowledge Management
  - Integration of information from external organizations into the NRC staff knowledge base for informed regulatory decision-making
  - External interactions and knowledge sharing, i.e. this technical exchange meeting



ADAMS No. ML19333B980

Action Plan Tasks

Task 1: Technical Preparedness

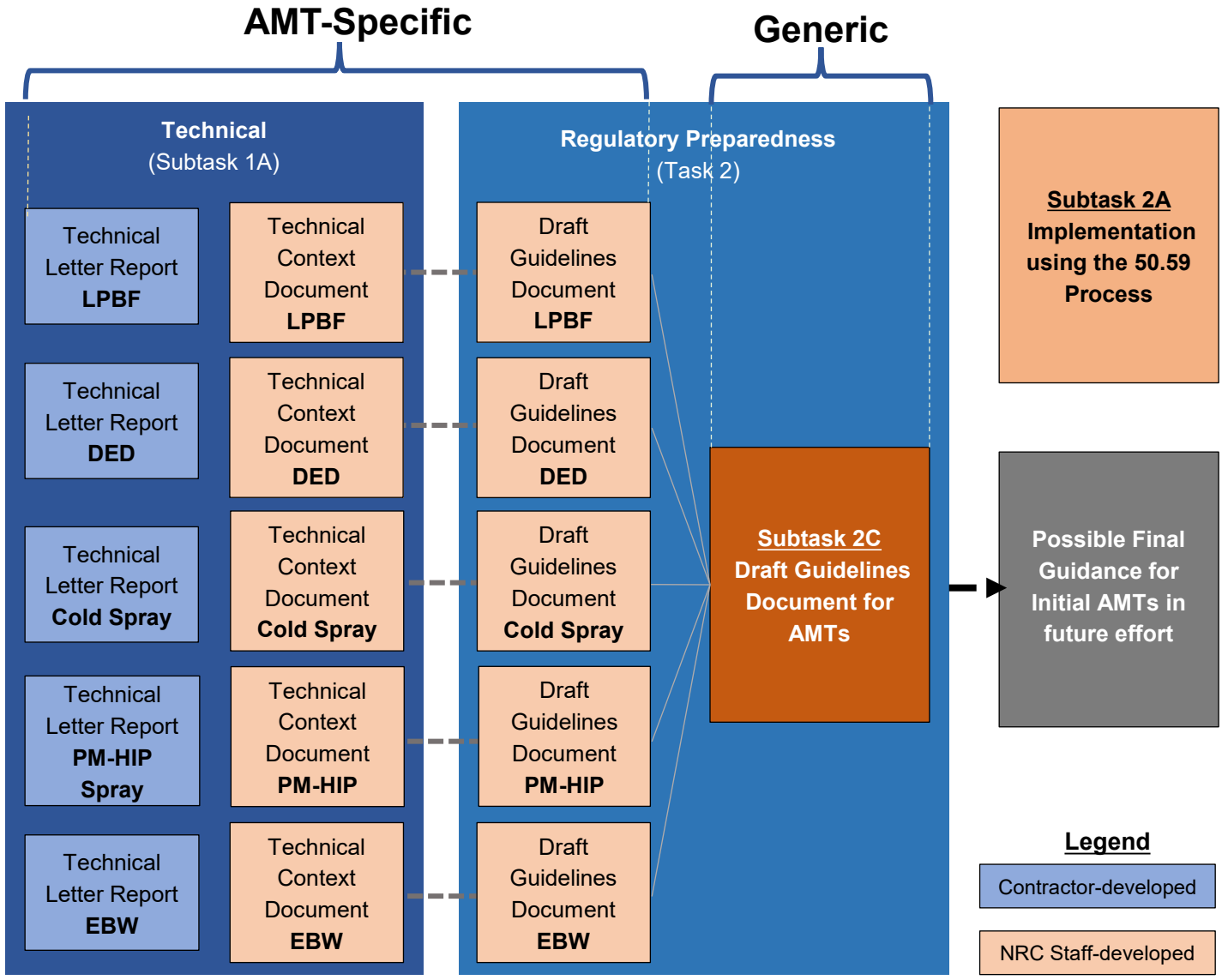
- Subtask 1A:AMT Processes under Consideration
- Subtask 1B: Inspection and Non-Destructive Examination (NDE)
- Subtask 1C: Modeling and Simulation of Microstructure and Properties

Task 2: Regulatory Preparedness

- Subtask 2A: Implementation using the 10 CFR 50.59 Process
- Subtask 2B: Assessment of Regulatory Guidance
- Subtask 2C: AMT Draft Guidelines Document

Task 3: Communications and Knowledge Management

- Subtask 3A: Internal Interactions
- Subtask 3B: External Interactions
- Subtask 3D: Public Workshop



Action Plan Reports

Generic

Subject	ADAMS Accession No.
AMT Action Plan, Rev. 1	ML19333B980
Draft review guidelines	ML21074A037
Implementation with 10 CFR 50.59 process	ML21155A043
Assessment of regulatory guidance	ML20233A693
NDE gap analysis	ML20349A012
Modeling gap analysis: microstructure	ML20269A301
Modeling gap analysis: performance	ML20350B550

Technology specific

	Technical Letter Report/ Technical Assessment	Draft Guidelines Documents
LPBD	ML20351A292	ML21074A040
L-DED	ML21301A077	ML22143A951
CS	ML21263A105	ML22143A952
EBW	ML22143A927	*TBD*
PM-HIP	ML22164A437	*TBD*

NRC AMT Public Website (https://www.nrc.gov/reactors/power/amts.html)

- Contains AMT-related documents and information

NRC Perspective on AMT in US Nuclear Industry

- Regulatory review preparations highly depend on awareness of industry interests, developments and advances
  - A couple of components have been introduced into US plants using the 50.59 process
- Codes and standards development is a key enabler
- Limited data is a challenge, esp. environmental effects (corrosion, irradiation)
- Effective and reliable NDE is critical to qualify and monitor the integrity of AMT components
- International developments:

  L-DED fabrication of a 3” class 1 valve - Korea

  Installation of AM water impeller - Slovenia

Former NRC Chair – visit to Advanced Manufacturing Pilot Facility at Georgia Tech

Current Regulatory Pathways

- Rulemaking
- License amendment (technical specification change, etc.)
- 10 CFR 50.59 Changes, tests and experiments
  - Subtask 2A of AMT Action Plan, Rev 1
- 10 CFR 50.55a Codes and Standards
  - Endorsement of Code edition and Code cases on AMTs
  - (z) alternatives to codes and standards

Nuclear Industry Involvement in AMT

Thimble Plugging Device
Installed in March 2020 in Byron Unit 2

Fuel assembly hardware
4 were installed in 2021 at Browns Ferry, harvesting one each cycle from 2023-2027

Ongoing Research

NEI NUCLEAR ENERGY INSTITUTE

Developed roadmap

EPRI ELECTRIC POWER RESEARCH INSTITUTE

SMRs, PM-HIP, LPBF

U.S. DEPARTMENT OF ENERGY

Technology Development for implementation

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Ongoing Staff Codes and Standards Activities

- ASME Special Committee on Use of Additive Manufacturing for Pressure Retaining Equipment
  - Developed criteria qualification document for LPBF - ASME PTB-13
  - 316L LPBF Data Package and Code Case template
  - Arc DED Data Package and Code Case template
  - Group will transfer to a new Standards group under Board of Pressure Technology Codes and Standards
- ASME Section III WG on AM (MF&E) Working Group on Advanced Manufacturing
  - Developing rules for fabrication of AM items, including support of AM Code Cases and new Section III Appendix for materials produced by AM processes
  - Preparing Arc DED and LPBF code cases
- ASME Section III, Division 5 Task Group on AM for High Temperature Applications
  - Developing Code actions for incorporating AM materials/components in ASME Section III, Division 5 (high temperature reactors) for elevated temperature nuclear construction
  - First application is 316H LPBF
- Many other activities in non-nuclear codes and standards

ADVANCE Act Section 401 - Report on Advanced Methods of Manufacturing and Construction for Nuclear Energy Projects

Section 401 Requirements

Examine

- Unique licensing issues or requirements relating to the use, for nuclear energy projects, of advanced manufacturing processes, advanced construction techniques, and rapid improvement or iterative innovation processes
- Requirements for nuclear-grade components in manufacturing and construction
- Potential use of standard materials, parts, or components in manufacturing and construction
- Potential use of standard materials to support or encapsulate new materials not yet in codes and standards
- Requirements related to the transportation of a fueled advanced nuclear reactor core from a manufacturing licensee to a licensee's site

Section 401 Requirements, continued

Identify

- Safety aspects of advanced manufacturing processes and advanced construction techniques that are not addressed by existing codes and standards
- Based on the results of the NRC's examination
  - Identify options for addressing the issues, requirements, and opportunities
  - Identify how domestic nuclear manufacturing and construction developers are impacted
  - Identify the extent to which Commission action is needed for implementation
- Include cost estimates, proposed budgets and timeframes

NRC Response

- Report was delivered January 2025
  - (https://www.nrc.gov/docs/ML2429/ML24292A171.pdf)
- Developed options with the potential to increase efficiency and reliability of review
  - Clarify areas of flexibility in regulations
  - Produce actionable guidance and review criteria for both technology neutral and technology specific topics
  - Enable use of alternate codes and standards in a consistent and efficient way

Table 2 – Ongoing NRC Program Actions Responsive to ADVANCE Act Section 401

Action	ADVANCE Act Section 401 Provision	Estimated Completion Timeframe
Develop a paper to the Commission evaluating options for providing regulatory flexibility in 10 CFR Part 52 during construction and operational phases (DD7)	(c)(1)(A)	Q2 fiscal year (FY) 2025
Develop design review lessons learned to improve the review process and guidance on rapid development and iterative innovation (DD6)	(c)(1)(A)(iii)	Q4 FY 2025
Develop the Advanced Reactor Construction Oversight Program (DI1)	(c)(1)(A)(ii)	Q1 FY 2026
Pre-application engagement on revision to approved topical report for steel-plate composite structures (DE2)	(c)(1)(A)(ii)	Q4 FY 2026
Develop guidance on seismic design of advanced reactors (DE3)	(c)(1)(C)	Q1 FY 2028

Table 3 – Potential New NRC Program Actions Related to ADVANCE Act Section 401

Action	ADVANCE Act Section 401 Provision(s)	Timeframe
Develop risk-informed and performance-based guidance on structural and mechanical review of components (DD2)	(c)(1)(B)(ii)	Q2 FY 2025 – Q1 FY 2026
Develop guidance on new materials that do not yet have applicable codes and standards (DD3)	(c)(1)(A) & (c)(1)(B)(iii)	Q2 FY 2025 – Q4 FY 2026
Develop guidance on accelerated material qualification (DD4)	(c)(1)(A)(iii)	Q2 FY 2025 – Q1 FY 2028
Develop guidance on examination of novel materials (DD5)	(c)(1)(C)	Q2 FY 2025 – Q1 FY 2028
Develop transport guidance for the use of new or nonnuclear technologies and provide greater manufacturing flexibility in package designs (N1)	(c)(1)(B)(iv)	Q2 FY 2025 – Q1 FY 2028
Develop guidance for structural monitoring of designs using advanced construction techniques (DE1)	(c)(1)(A)(ii)	Q2 FY 2025 – Q1 FY 2027

NRC Activities – Moving Forward

- Research tasks include:
  - Assessment of 1 additional : Wire-Arc DED
  - NRC AMT Workshop: Oct. 2023
- Completed NRC documents and updates: https://www.nrc.gov/reactors/power/amts.html
- Continue NRC participation in ASME Code activities
- Performance of NDE confirmatory efforts on AMT components, mock-ups, welds, etc.
  - Collaborations leading sharing mockups and test results.
- Implementation of ADVANCE Act deliverables

NRC AMT Points-of-contact

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THANK YOU