

OVERVIEW OF U.S. NRC AMT ACTIVITIES

2023 NRC Workshop on Advanced Manufacturing
Technologies for Nuclear Applications

October 24-26, 2023
NRC HQ, Rockville, MD

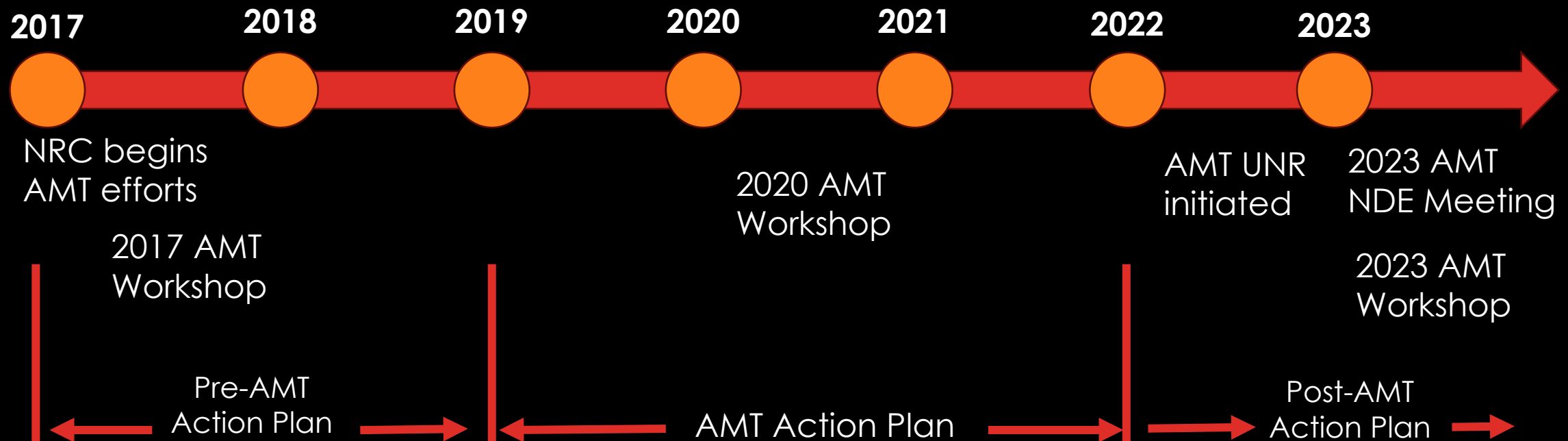
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DRIVERS FOR NRC ACTIVITIES

- A variety of stakeholders are working toward more widespread use in both existing and future nuclear applications:
 - Vendors and licensees/applicants
 - Identifying candidate applications
 - Developing technical bases for gaining regulatory acceptance
 - Nuclear Energy Institute – Developed advanced manufacturing methods (AMM) roadmap to understand industry needs/interests and assist with regulatory acceptance (2019)
 - Electric Power Research Institute – Developing techniques for large components in small modular reactors, developing data package for LPBF and WA-DED ASME draft Code Cases
 - US Department of Energy – Developed the AMMT 2022 Roadmap
 - Performing basic and applied research, technology development, data infrastructure, and developing a qualification framework to support AMT implementation

NRC AMT ACTIVITIES TIMELINE



2017 NRC AMT WORKSHOP

- The objectives of the workshop were to cover topics including:
 - The state-of-the-art of AM
 - Industry activities
 - Irradiation testing and effects on AM
 - AM qualification
 - Codes & standards
 - NDE
 - Cybersecurity
 - Regulatory perspectives
- Outcomes:
 - Proceedings of the workshop published as NUREG/CP-0310 ([ML19214A205](#))
 - Next steps included further engagement with industry.

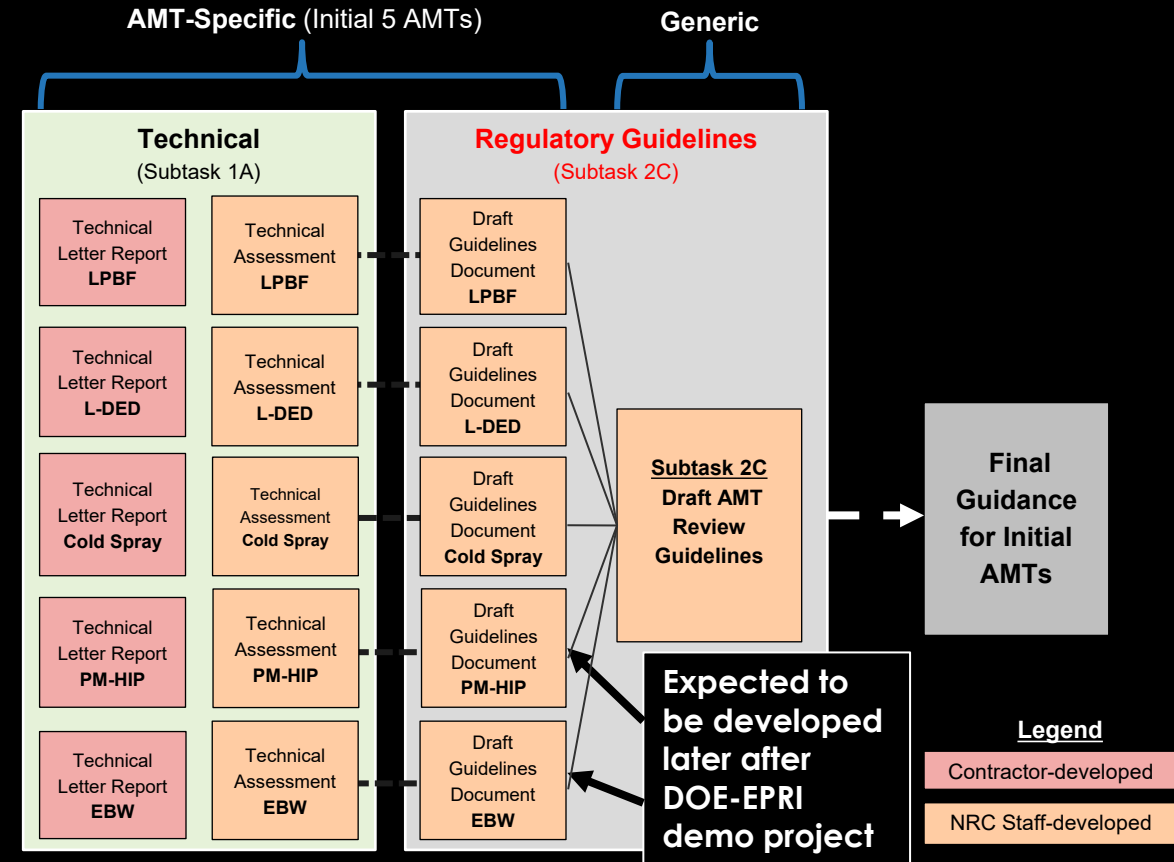


AMT ACTION PLAN (2019-2022)

- The NRC completed the AMT Action Plan which accomplished the following objectives:
 - Assessed the safety significant performance-based differences between AMTs and traditional manufacturing processes.
 - Prepared the NRC staff for potential reviews (five AMTs, modeling, and NDE).
 - Identified and addressed AMT characteristics pertinent to safety that are not managed or addressed by codes, standards, regulations, etc.
 - Risk-informed and performance-based perspective
 - Provided draft Staff guidance and tools for review consistency, communication, and knowledge management.
- Revision 1 of the AMT Action Plan was published in June 2020 ([ML19333B980](#)).

AMT ACTION PLAN (CONT.)

- NRC AMT Action Plan products:
 - Technical Letter Reports (TLRs)
 - Provide technical bases information and gap analyses
 - Prepared by NRC contractors (to date, DOE labs)
 - Technical assessments (TAs)
 - Provides the NRC staff perspective on key aspects of the AMT for safety and component performance.
 - Draft guidelines documents (DGDs)
 - Informed by the TA and TLR and generated by the NRC staff for each AMT.
 - Please visit the NRC AMT public website to download the available reports:
 - <https://www.nrc.gov/reactors/power/amts.html#status>



AMT ACTION PLAN PRODUCTS

| Subtask | Actions/Deliverables | Status |
|--|---|--|
| 1A AMT processes under consideration | Additive Manufacturing (AM) – Laser Powder Bed Fusion | Complete - ML20351A292 |
| | AM – Directed Energy Deposition (DED) | Complete - ML21301A077 |
| | Cold Spray | Complete - ML21263A105 |
| | Powder Metallurgy (PM) – Hot Isostatic Pressing (HIP) | Complete - ML22134A437 |
| | Electron Beam (EB) welding | Complete - ML22143A927 |
| 1B Inspection and NDE | NDE gap analysis | Complete - ML20349A012 |
| 1C Modeling and Simulation of Microstructure | M&S gap analysis to predict microstructures | Complete - ML20269A301 |
| | ANL M&S gap analysis to predict material performance | Complete - ML20350B550 |

AMT ACTION PLAN PRODUCTS

| Subtask | Actions / Deliverables | Status |
|--|---|---|
| 2A 50.59 process | Finalize document incorporating feedback from Regional staff regarding the 10 CFR 50.59 process | Complete - ML21200A222 |
| 2B Assessment of regulatory guidance | Path forward on guidance development or modification | Complete - ML20233A693 |
| 2C AMT Guidance Document | Draft AMT Review Guidelines | Complete - ML21074A037 |
| | Draft Guidelines Documents for specific AMTs | AM-Laser Powder Bed Fusion - ML21074A040 AM-Laser-Directed Energy Deposition - ML22143A950 Cold Spray - ML22143A950 |
| 3A/3B External / Internal Interactions | Continued communication with NRC staff and external stakeholders for AMT-related activities | Ongoing as needed |
| 3C Knowledge Management Plan | Develop Knowledge Management Plan | Complete - internal |
| 3D Workshop | Hold public workshop | Complete - Public Meeting Summary: ML20357B071 RIL: Part 1 Part 2 |
| 3E Material Information course | Training course and course materials | First 6 seminars complete - internal |

2020 NRC AMT WORKSHOP

- The objectives of the workshop were to cover topics including:
 - nuclear industry implementation plans
 - codes and standards activities
 - research findings
 - qualification & aging management
 - regulatory approaches in other industries.
- Key Takeaways:
 - AMTs are being incorporated!
 - Use of PM-HIP with EBW for larger nuclear components looks promising, but requires larger HIP and EBW capabilities
 - AMT technologies evolve quickly, outpacing the qualification and licensing process
 - Target applications to optimize unique AM characteristics
 - SDOs need continual communication to reduce redundant standards development



Exelon



2020 NRC AMT WORKSHOP: NEXT STEPS

Selected Next Steps

Nuclear industry / NRC: Use data from existing AMT applications to help justify and increase confidence in further applications of AMTs



Nuclear industry / NRC: Potential nuclear applications of AMTs may benefit from non-nuclear applications.



Support intelligent, performance-based qualification framework



My Perspective

This is an ongoing process as experience is gained from existing nuclear applications of AMT components (e.g., thimble plugging device, channel fastener).

Non-nuclear applications in relevant service conditions (e.g., temperature) are helping to inform NRC assessments of AMTs

DOE AMMT Roadmap and the America Makes Roadmap are helping greatly in this area.

2020 NRC AMT WORKSHOP: NEXT STEPS

Selected Next Steps

Continue developing technical basis for utilizing these technologies in nuclear applications



Gain ASME acceptance and obtain regulatory approval



Continue to evaluate research needs and technology gaps



My Perspective

ASME activities to develop data packages for Code Cases are helping greatly in this area.

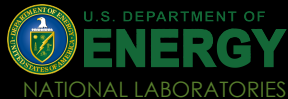
ASME Code Cases have been and/or are being developed for LPBF, PM-HIP, and DED.

EPRI and DOE efforts are supporting this area.

The NRC to continues to assess AMTs and perform gap analyses. Knowledge/data gaps may help identify research needs.

2023 MEETING ON NDE OF AM COMPONENTS

- The meeting focused on the state-of-the-art of NDE of AM components, as well as key challenges associated with the use of these technologies. Specific topics included:
 - Ultrasonic testing (phased array, FMC/TFM)
 - Process compensated resonance testing
 - Qualification
 - Structure-property relationships
 - In-process monitoring
- Key Takeaways:
 - Integrate NDE with the design and manufacturing process of AM components.
 - Continue NRC engagement to inform staff of applicable challenges relevant to the adoption of AM components in nuclear plants.
 - The final surface condition of AM components is an important consideration for examinations.
 - Standardization of NDE calibration methods and how that applies to the different AM manufacturing processes is needed.
 - Staff gained a better understanding of AM microstructures and effects on material properties.



PennState



Meeting summary: [ML23153A010](#)



CURRENT NRC AMT ACTIVITIES

- Continue to prepare:
 - Technical preparedness
 - AMT assessments, NDE of AMT components, data & modeling for qualification
 - Products: technical letter reports, technical assessments
 - Regulatory preparedness
 - Regulatory guidance
 - Communications and Knowledge Management
 - Internal & external interactions, KM, workshops, staff training
- Reports in review:
 - Wire-arc directed energy deposition
 - Hybrid manufacturing
 - In-process monitoring

THE END