

# 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

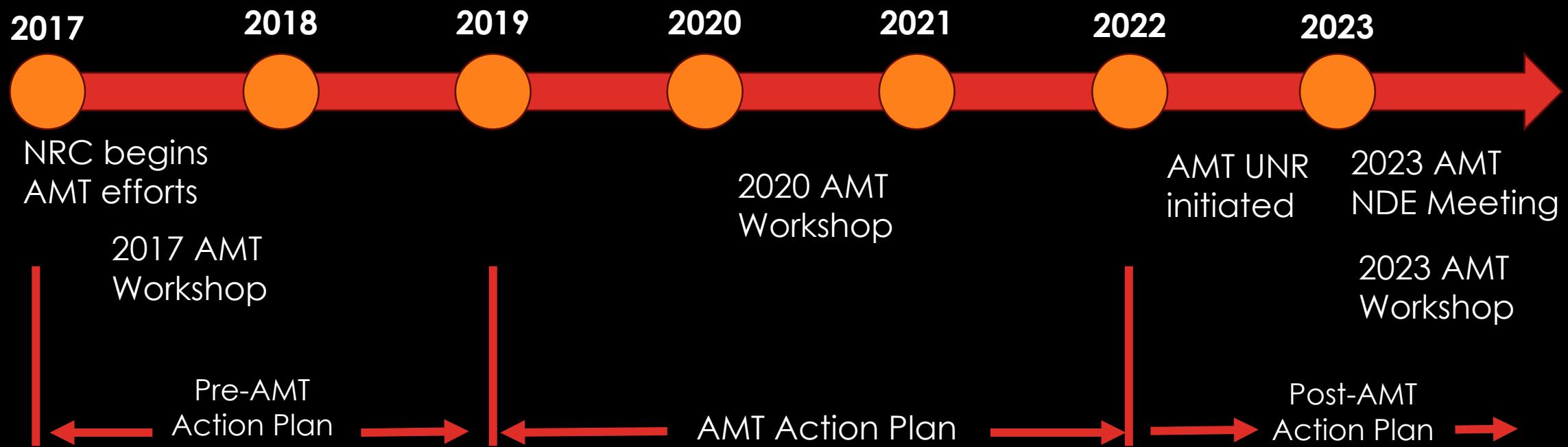
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The views expressed by the author do not necessarily  
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# DRIVERS FOR NRC ACTIVITIES

- 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.

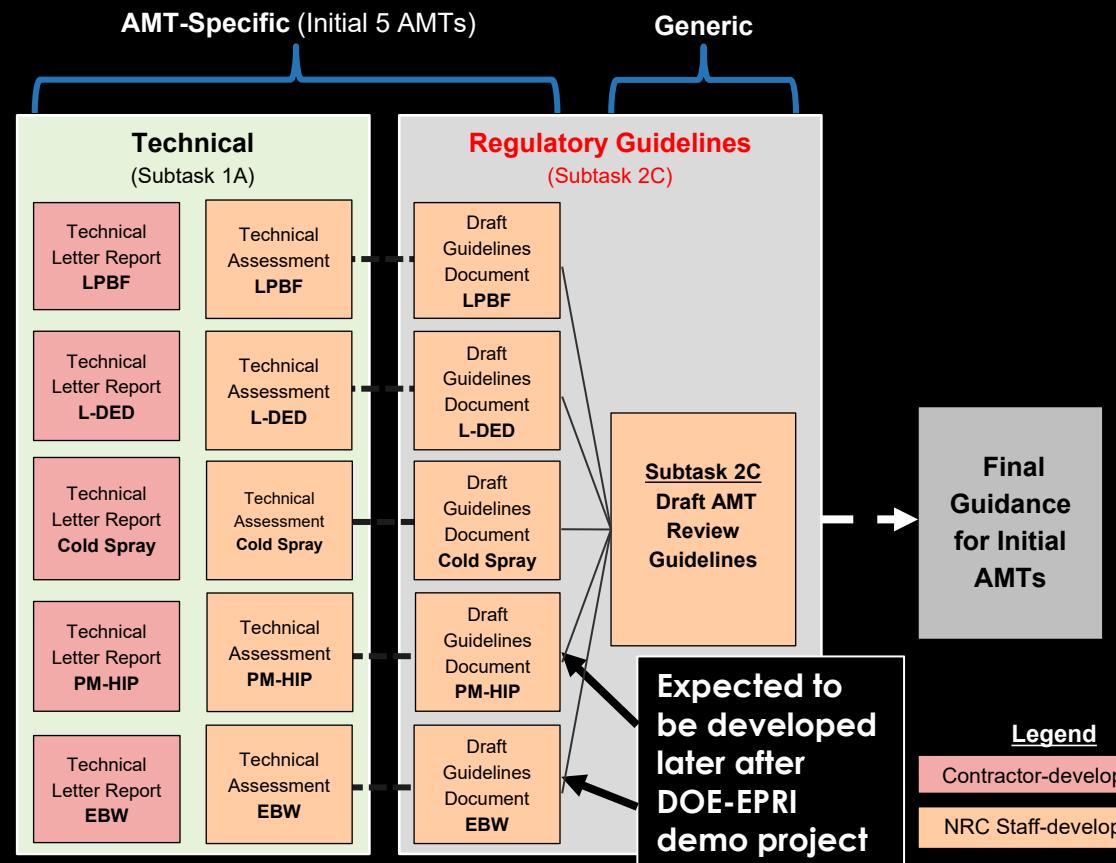


# AMT ACTION PLAN (2019-2022)

- 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 - <a href="#">ML20351A292</a>
	AM – Directed Energy Deposition (DED)	Complete - <a href="#">ML21301A077</a>
	Cold Spray	Complete - <a href="#">ML21263A105</a>
	Powder Metallurgy (PM) – Hot Isostatic Pressing (HIP)	Complete - <a href="#">ML22134A437</a>
	Electron Beam (EB) welding	Complete - <a href="#">ML22143A927</a>
1B Inspection and NDE	NDE gap analysis	Complete - <a href="#">ML20349A012</a>
1C Modeling and Simulation of Microstructure	M&S gap analysis to predict microstructures	Complete - <a href="#">ML20269A301</a>
	ANL M&S gap analysis to predict material performance	Complete - <a href="#">ML20350B550</a>

# 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 - <a href="#">ML21200A222</a>
2B Assessment of regulatory guidance	Path forward on guidance development or modification	Complete - <a href="#">ML20233A693</a>
2C AMT Guidance Document	Draft AMT Review Guidelines	Complete - <a href="#">ML21074A037</a>
	Draft Guidelines Documents for specific AMTs	AM-Laser Powder Bed Fusion - <a href="#">ML21074A040</a> AM-Laser-Directed Energy Deposition - <a href="#">ML22143A950</a> Cold Spray - <a href="#">ML22143A950</a>
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: <a href="#">ML20357B071</a> RIL: <a href="#">Part 1</a> <a href="#">Part 2</a>
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



# 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 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