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# **NRC Agency Action Plan for Advanced Manufacturing Technologies**

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U.S. Nuclear Regulatory Commission

November 8, 2021

# Advanced Manufacturing Technologies

## Techniques and material processing methods

- Not traditionally used in the U.S. nuclear industry
- Not formally standardized/codified by the nuclear industry
- AMTs can include new ways to fabricate or join components, surface treatments, or other processing techniques to provide a performance or operational benefit.

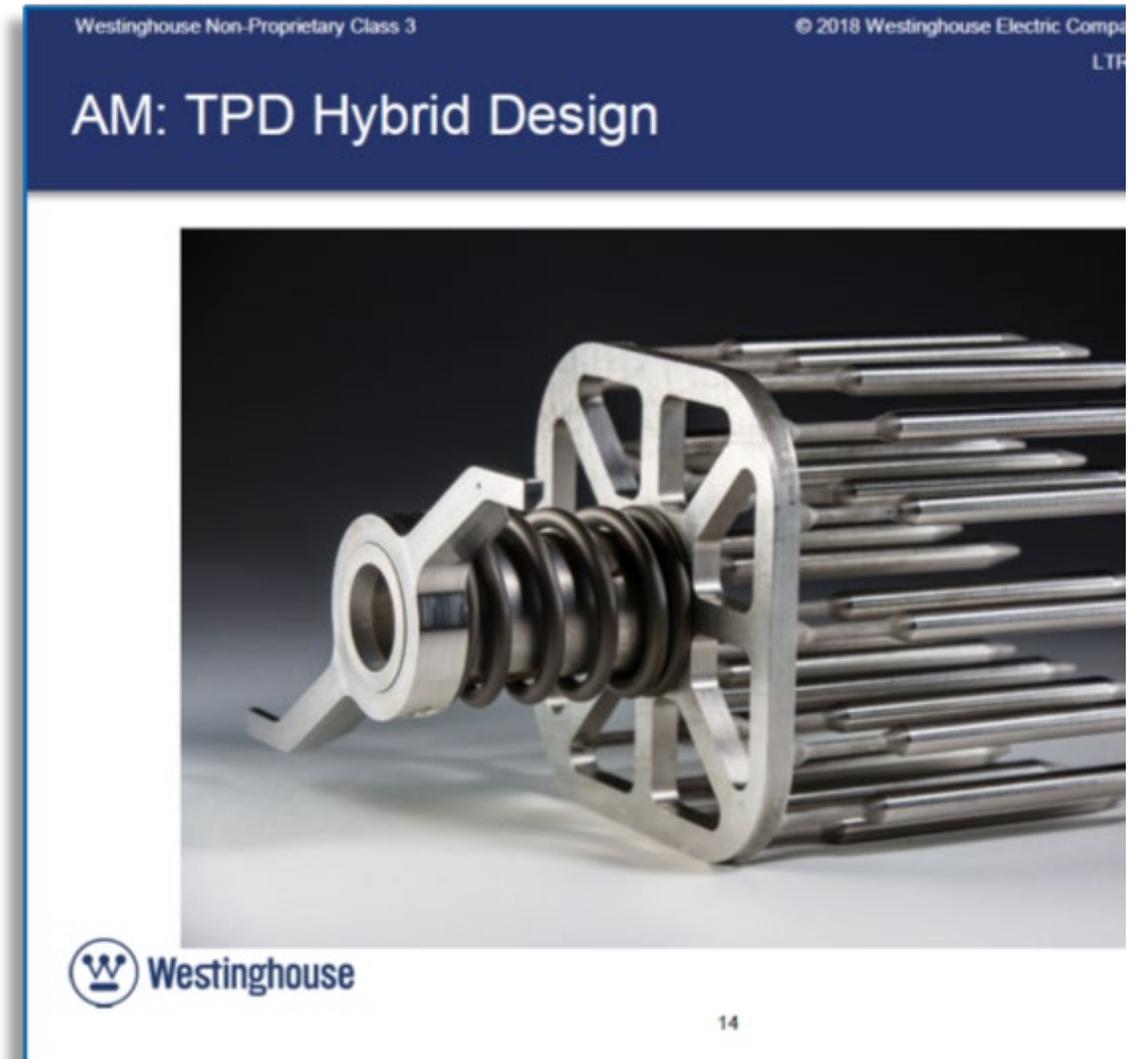
## Initial AMTs based on industry interest:

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

# AMT Action Plan

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- In June 2020, the NRC drafted Revision 1 of its Advanced Manufacturing Technologies Action Plan (NRC Agencywide Documents Access and Management System (ADAMS) Accession No. ML19333B980):
  - Assess the need for guidance updates
  - Ensure NRC staff preparedness to review AMT applications for the Nuclear Industry



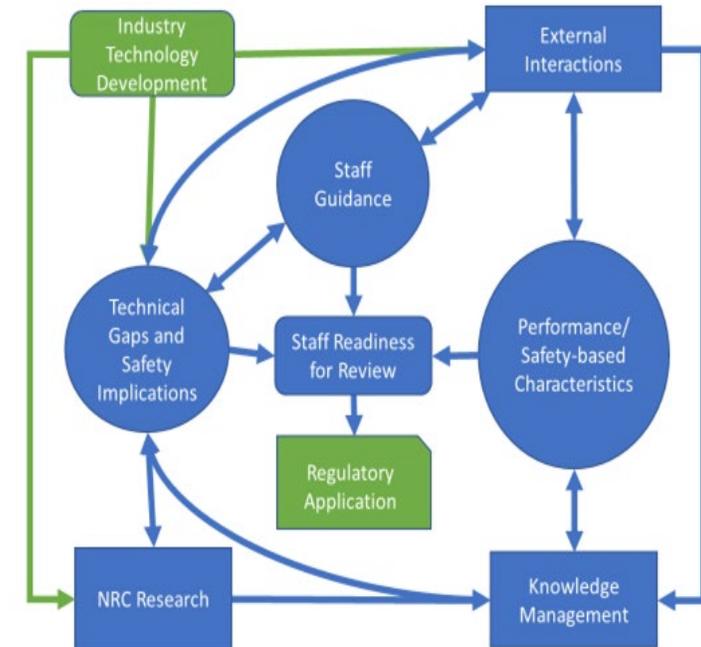
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# AMT Activities

- AMTs are becoming increasingly applicable to the nuclear industry – technology development and possible implementation are moving rapidly
- Industry Activities
  - DOE Advanced Method of Manufacturing Program
  - NEI roadmap on regulatory acceptance
  - EPRI/industry efforts on technology development
  - ASME and ASTM efforts on standards development
  - Significant efforts by other organizations (DOD, NASA, NIST, etc.)
- NRC Activities and Regulatory Needs
  - NRC Action Plan on AMTs
    - Prepare NRC for expected submittals to use AMTs in nuclear applications
    - Develop expertise and guidance to support regulatory review of AMTs
  - Identify technical gaps and establish knowledge base for selected AMTs
  - Engage with external organizations to leverage knowledge base and identify knowledge gaps

# Action Plan, Rev. 1 - Tasks

- Task 1 - Technical Preparedness
  - Technical information, knowledge and tools to prepare NRC staff to review AMT applications
- Task 2 - Regulatory Preparedness
  - Guidelines to prepare staff for efficient and effective review of AMT-fabricated components submitted to the NRC for review and approval
- Task 3 - Communications and Knowledge Management
  - Integration of information from external interactions
  - Knowledge management, i.e. AMT Workshop



# Task 1 – Technical Preparedness Activities

## Subtask 1A: AMT Processes under Consideration

- Perform a technical assessment of multiple selected AMTs of interest
- Gap assessment for each selected AMTs vs traditional manufacturing techniques
- Technical assessment document for each report developed by AMT team
  - **LPBF Technical Letter Report (ML20351A292)**
  - **Cold Spray Technical Letter Report (ML21263A107)**

## Subtask 1B: Inspection and NDE

- Literature survey of the current state of the art of non-destructive examination (NDE) of components made using AMTs: **Complete (ML20349A012)**.

## Subtask 1C: Modeling and Simulation of Microstructure and Properties

- Evaluate modeling and simulation tools used to predict the initial microstructure, material properties and component integrity of AMT components
- Identify existing gaps and challenges that are unique to AMT compared to conventional manufacturing processes:
  - **Predicting Initial Microstructures: Complete (ML20269A301)**
  - **Predicting Material Performance: Complete (ML20350B550)**

# Task 2 – Regulatory Preparedness Activities

- Subtask 2A: Implementation using the 10 CFR 50.59 Process
  - Provide guidance and support to regional inspectors regarding AMTs implemented under 50.59: **Complete (ML21155A043)**
- Subtask 2B: Assessment of Regulatory Guidance
  - Assess whether any regulatory guidance needs to be updated or created to clarify the process for reviewing submittals with AMT components: **Complete (ML20233A693)**
- Subtask 2C: AMT Guidelines Document
  - Develop a report which describes the generic technical information to be addressed in AMT submissions. Technology specific guidelines also developed.
  - Public meeting scheduled held September 16, 2021, to discuss:
    - **Draft AMT Review Guidelines (ML21074A037)**
    - **Draft Guidelines Document for AM-LPBF (ML21074A040)**

# Subtask 2C - Draft AMT Review Guidelines

- Provides guidelines to assist NRC staff reviewing requests to use AMTs
- Identifies the range of information that could be necessary in a submittal
- Information provided in a submittal would depend on several factors
  - Maturity of the AMT
  - Codes and standards
  - Prior precedent
  - Safety significance of the intended use of the AMT
- Could potentially be used for staff review of new material and material for new or advanced reactors. Not applicable to the fuels area
- Concepts could be considered for transportation and storage under 10 CFR Part 71 and Part 72

# Subtask 2C - Draft AMT Review Guidelines

- Provides generic information to be supplemented with separate AMT-specific draft guidelines documents on the following
  - the differences between the AMT relative to traditional manufacturing methods
  - the safety significance of the identified differences
  - the aspects of each AMT that are not currently addressed by codes and standards or regulations
- AMT specific guidelines documents will address five AMTs
  - laser powder bed fusion (LPBF)
  - laser directed energy deposition (L-DED)
  - powder metallurgy – hot isostatic pressing (PM-HIP)
  - electron beam (EB) welding
  - cold spray

# Subtask 2C - Draft AMT Review Guidelines

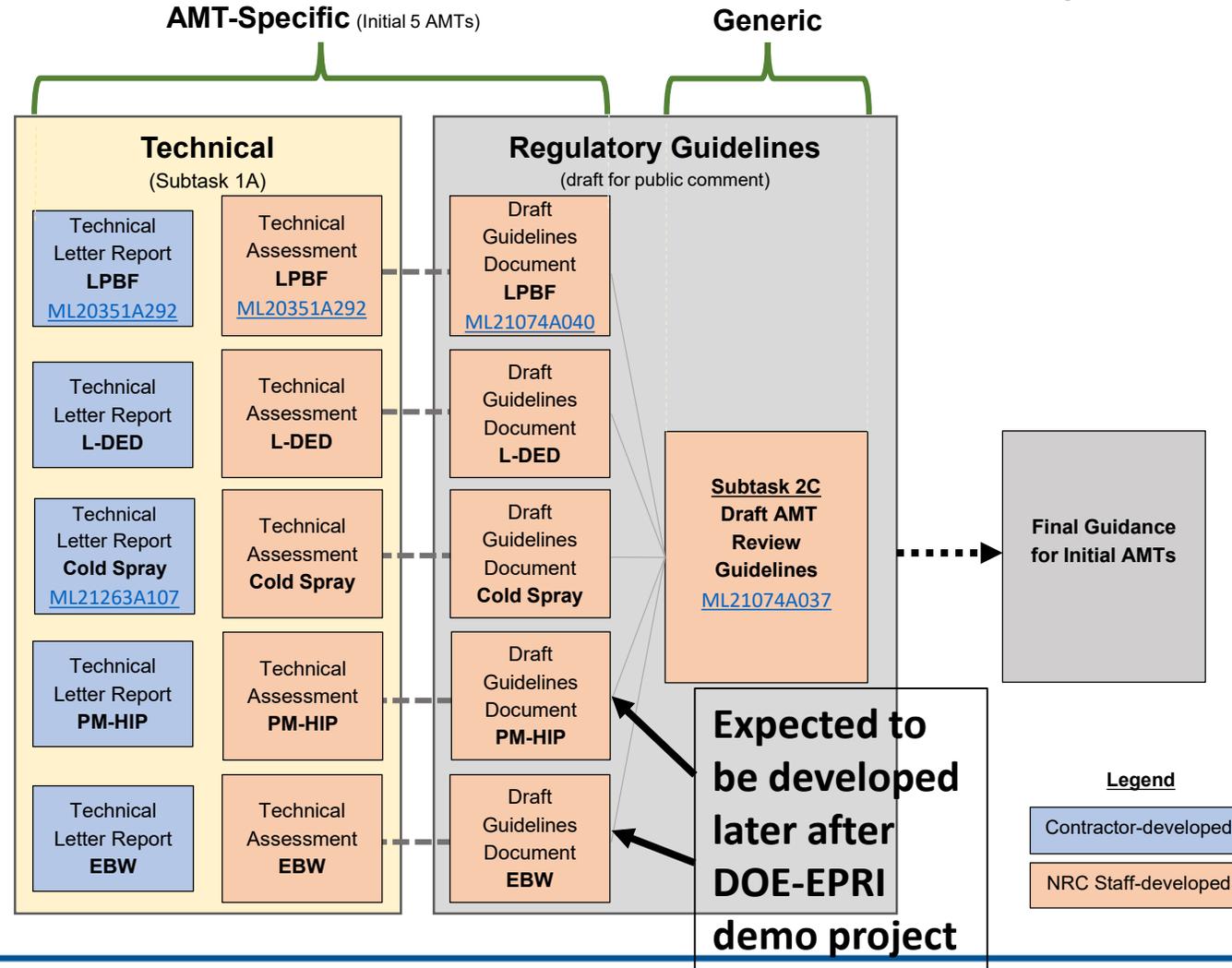
- General Review Philosophy
  - Sufficient
    - All important (i.e., safety-significant or safety-related) attributes for the specific application of an AMT are addressed in sufficient technical depth to justify its use.
  - Flexible
    - A variety of both technical and regulatory approaches can be used to demonstrate that these important attributes are addressed.
  - Minimize technical and regulatory burden
    - The level of detail in which a submittal must address the applicable requirements and technical basis may vary depending on the safety significance of the application and the maturity of the AMT.

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# NRC Guidelines for AMT

- A Technical Letter Report (TLR) will be generated for each of the initial five AMTs (i.e., LPBF, L-DED, Cold Spray, Electron Beam Welding, PM-HIP)
  - Provides technical basis information and gap analysis
  - Written by NRC contractors (National Labs)
- A Technical Assessment (TA) document will be prepared for each TLR by NRC staff to provide context to the gaps identified in the TLR from NRC's perspective. Highlights key technical information related to the specific AMT's use for nuclear applications
- A Draft Guidelines Document (DGD) will be generated by NRC staff from the TA and TLR for each AMT to accompany the **AMT Review Guidelines**

# NRC AMT Guidelines Development



# Task 3 – Communications and KM Activities

## Subtask 3A: Internal Interactions

- Internal coordination with NRC staff in other areas (e.g., advanced reactors, dry storage, fuels)

## Subtask 3B: External Interactions

- Engagement with codes and standards, industry, research, international

## Subtask 3C: Knowledge Management

- Seminars, public meetings, training, knowledge capture tools

## Subtask 3D: Public Workshop

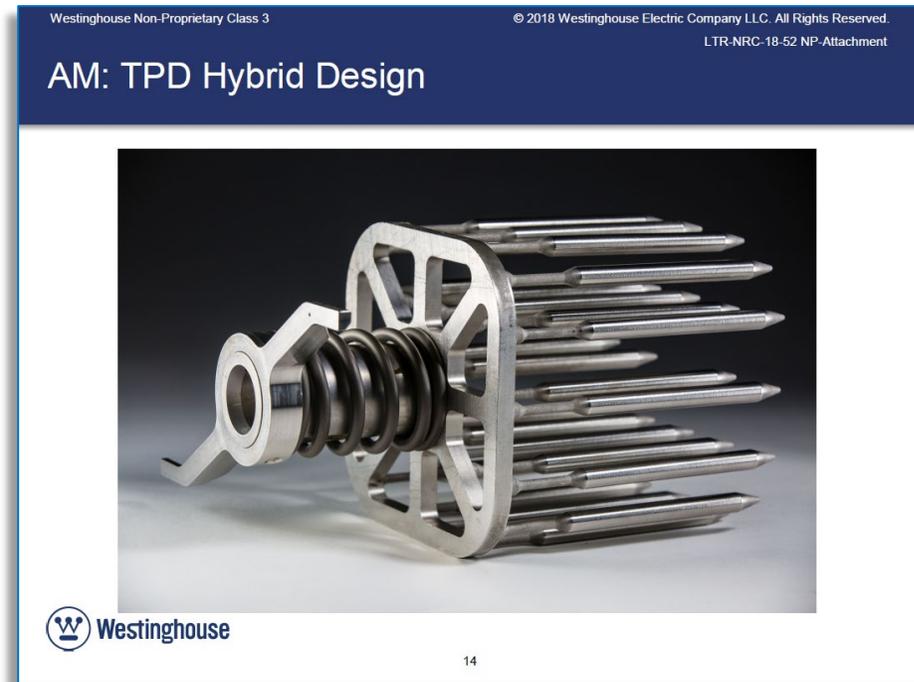
- **RIL 2021-03: Part 1 (ML21113A081), Part 2 (ML21113A082)**

## Subtask 3E: AMT Materials Information Course

- Internal NRC staff training
- 5 seminars to date on a variety of topics

# First US Application of Additive Manufacturing

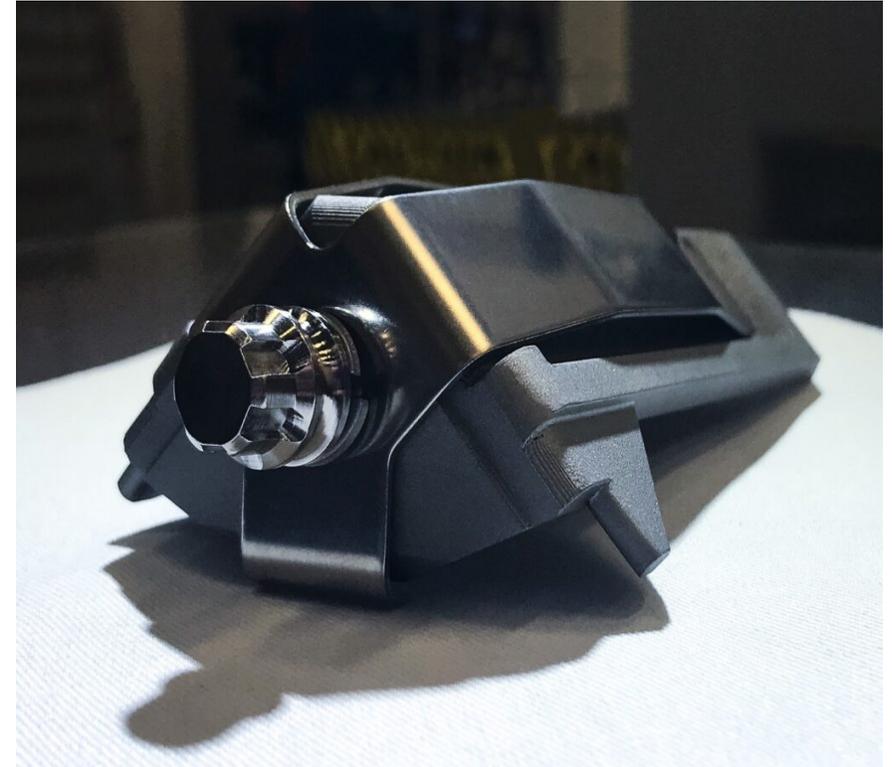
- Thimble Plugging Device
  - Installed in March 2020 in Byron Unit 1
  - 316L stainless steel – LPBF
  - Very low safety significant component (Non ASME B&PV Code class)
  - PWR environment with irradiation
  - Installation done without prior NRC approval under 10 CFR 50.59



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# Second US Application of Additive Manufacturing

- Channel Fastener
  - Installed in April 2021 at Browns Ferry Unit 2
  - 316L stainless steel – LPBF
  - Non ASME B&PV Code Class
  - BWR environment with irradiation
  - Installation done without prior NRC approval under 10 CFR 50.59



<https://www.powermag.com/nuclear-first-3d-printed-safety-related-components-installed-at-browns-ferry/>

Credit: Framatome

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# NRC AMT Action Plan Deliverables Currently Publicly Available

- Task 1A Laser Powder Bed Fusion TLR and technical assessment [ML20351A292](#)
- Cold Spray TLR [ML21263A107](#)
- Task 1B NDE Gap analysis [ML20349A012](#)
- Task 1C Modeling and Simulation of Microstructure
  - Gap analysis to predict microstructure [ML20269A301](#)
  - Gap analysis to predict material performance [ML20350B550](#)
- Task 2A 10 CFR 50.59 process [ML21200A222](#)
- Task 2B Assessment of regulatory guidance [ML20233A693](#)
- Task 2C Guidelines Document
  - Draft AMT Review Guidelines [ML21074A037](#)
  - Draft Guidelines Document for AM –LPBF [ML21074A040](#)
- Task 3D NRC Workshop on AMTs for Nuclear Applications
  - RIL 2021-03: [Part 1](#) [Part 2](#)

Questions ??????

