



**Pacific
Northwest**
NATIONAL LABORATORY

Stakeholder Collaboration and Qualification Methodologies

Isabella van Rooyen

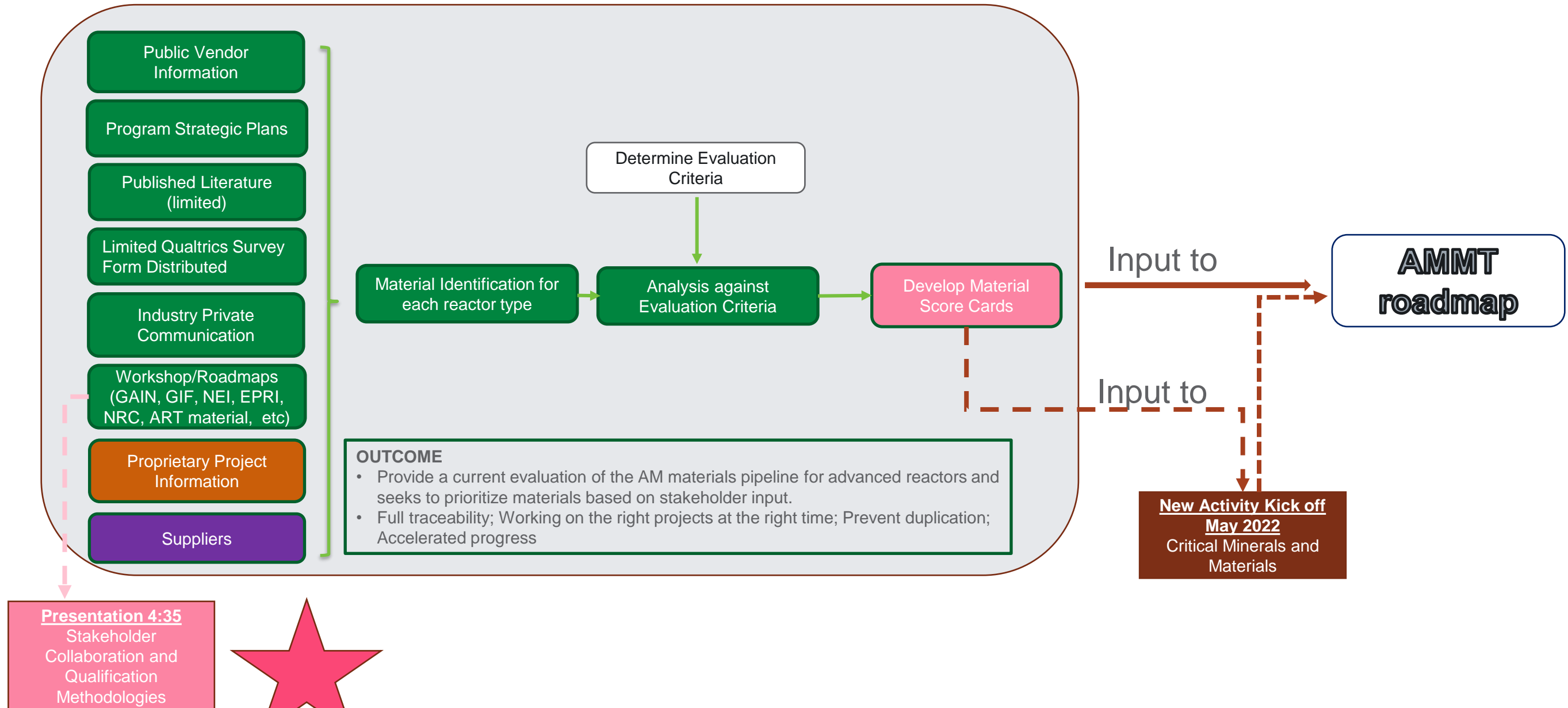


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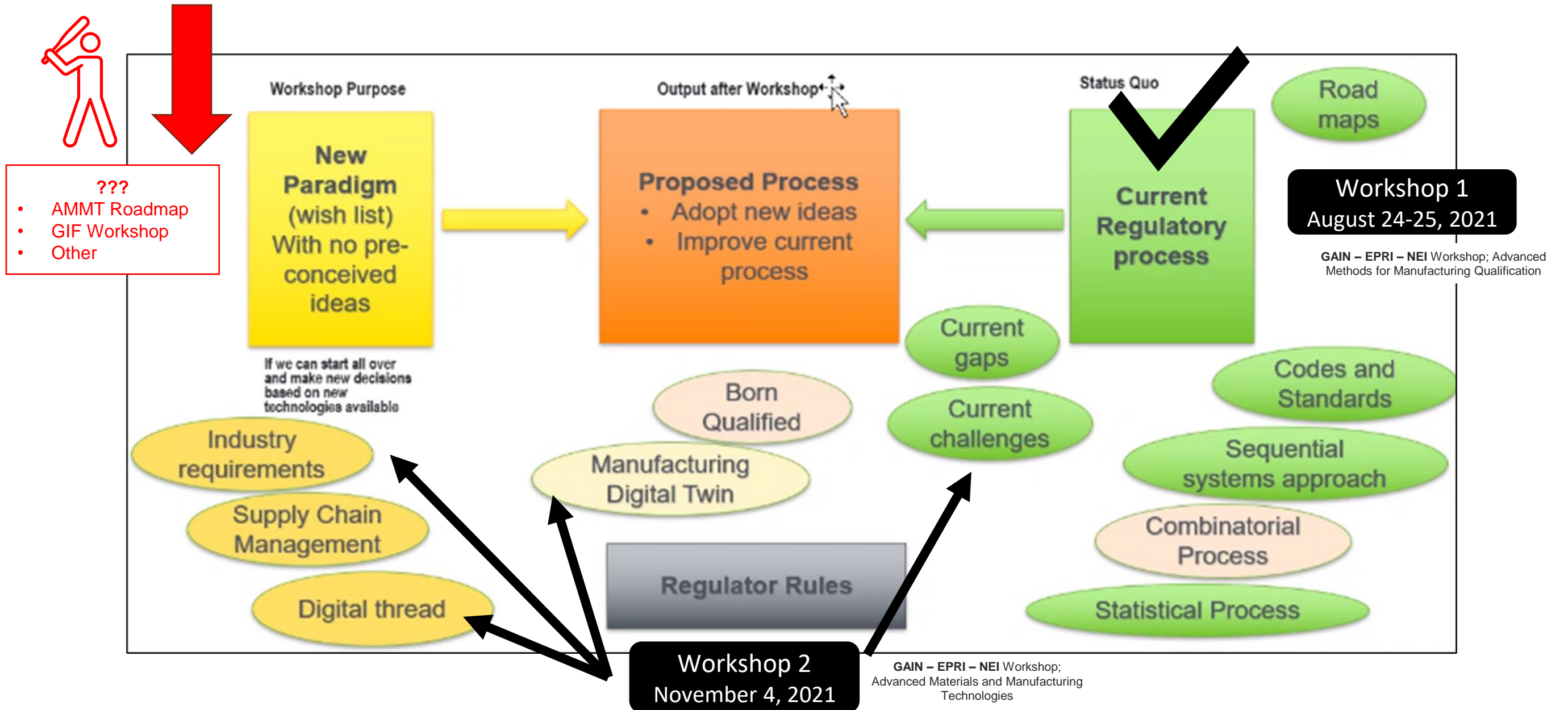
AMMT Program Review May 18-19, 2022; Virtual Meeting
PNNL-SA-173271.



AMMT Projects Analysis and Prioritization Process: Material focused



Qualification Workshop Series



GAIN – EPRI – NEI Workshop

Advanced Methods for Manufacturing Qualification

August 24-25, 2021

GAIN-EPRI-NEI		AUGUST 24-25, 2021	
Advanced Methods for Manufacturing QUALIFICATION WORKSHOP		Virtual Workshop GAIN.INL.GOV/Workshops	
AGENDA			
Tuesday, August 24, 2021			
Time (EDT)	Setting the Stage	Presenter	
11:00 a.m.	Welcome / Workshop Overview / Virtual Meeting Logistics	Isabella van Rooyen, INL	
11:10 a.m.	Industry Collaboration (GAIN, EPRI, NEI)	Lori Braase, GAIN Andrew Sowder, EPRI Everett Redmond, NEI	
11:25 a.m.	DOE-NE AMM Program	Dirk Cairns-Gallimore, DOE-NE	
11:35 a.m.	Setting the Stage: Future Opportunities	Isabella Van Rooyen, INL	
Current Standards for Materials and Component Qualification, and the Regulatory Process		Dave Gandy, EPRI	
11:50 a.m.	• "Big Picture View"	Jason Christensen, INL	
12:00 p.m.	• ASME BPV II Materials – Conventional ASME Materials Qualification	Jay Cameron, HSB	
12:25 p.m.	• ASME BPV-III Division 5 – High Temperature Nuclear Materials Qualification	Richard Wright, INL	
12:50 p.m.	• ASME BPV-III MF&E Advanced Manufacturing and Qualification	Daniel Mann, Flowserve	
1:10 p.m.	• NRC Perspective	Robert Davis, US NRC	
1:30 p.m.	Break		
1:45 p.m.	• ASME Non-Metallics Materials Working Group Activities	Kate Hyam, ASME	
2:05 p.m.	• ASTM Standards Overview	Shane Collins, ASTM	
2:15 p.m.	Q&A / Discussion		
Digital Threads and Modeling (Databases of Properties)		Ram Devanathan, PNNL Ed Herderick, OSU	
2:35 p.m.	• Demonstration of Digital Threads Application	Ryan DeHoff, ORNL	
2:50 p.m.	• Machine Learning	Mohammad Abdo, INL	
3:05 p.m.	• Digital Thread Factory – Metrology, Quality, and Modeling	Jeff Robertson, Simufact	
3:20 p.m.	• Digital Thread for Additive Manufacturing and Nuclear Case Study	Tim Bell, Siemens	
3:35 p.m.	• Design, Fabrication and Testing of Scaled Components	Per Peterson, Kairos	
3:50 p.m.	Q&A / Discussion		
4:10 p.m.	Closing Remarks	Isabella van Rooyen, INL	

Krynicky – August 16, 2021

GAIN-EPRI-NEI		AUGUST 24-25, 2021	
Advanced Methods for Manufacturing QUALIFICATION WORKSHOP		Virtual Workshop GAIN.INL.GOV/Workshops	
AGENDA			
Wednesday, August 25, 2021			
Time (EDT)	"Real Life" Application and Capability	Presenter	
11:00 a.m.	Welcome	Andrew Sowder, EPRI Everett, Redmond, NEI	
Supply Chain Opportunities and Challenges		Marc Albert, EPRI	
11:10 a.m.	• Opportunities & Challenges in AMM Procurement	Jason Hurst, Nuscale Power	
11:25 a.m.	• Opportunities & Challenges in AMM Component Qualification and Supply	Teresa Melfi, Lincoln Electric	
11:40 a.m.	• Supplier Challenges	Christine Burow, KSB	
11:55 a.m.	• Qualifying Additively Manufactured Advanced Reactor System Parts	Derek Rountree, Luna Innovation	
12:10 p.m.	• Supply Chain Development and Qualification Processes	John Shingledecker, EPRI	
12:25 p.m.	• Microreactor Supply Challenges	Pavel Tsvetkov, TAMU	
12:40 p.m.	Q&A / Discussion		
Lessons Learned – Success Stories - Accomplishments		Ed Herderick, OSU	
1:00 p.m.	• FOAK Deployment – Thimble Plug	David Huegel, Westinghouse	
1:15 p.m.	• FOAK Deployment – Channel Fastener	Christopher Wiltz, Framatome	
1:30 p.m.	• ASME Code Case Development for 316L SS Using PM-HIP	David Gandy, EPRI	
1:45 p.m.	Q&A / Discussion		
2:00 p.m.	Break		
Nuclear Industry / End User Feedback (Day 1 Presentations) and AMM Needs (Materials, Components, Digital Systems, Supply Chain etc.)		Hilary Lane, NEI	
2:15 p.m.	• Molten Salt Reactors	Lauren Lathem, Southern Co.	
2:30 p.m.	• High Temperature Reactors	Farshid Shahrokhi, Framatome	
2:45 p.m.	• Fast Reactors	John Hanson, Oklo	
3:00 p.m.	• Microreactor Unique Considerations and Relevant Needs	Holly Trellue, LANL	
3:15 p.m.	• Existing Fleet Component Testing and Relevant Needs	Lee Friant, Exelon	
3:30 p.m.	Q&A / Discussion		
3:50 p.m.	AMM Qualification Workshop – Part II: Brainstorming Sessions – November 4, 2021 (Proposed session topics, process/purpose/expected outcomes, teams, team leaders, etc.)		
	• What are the major materials qualification issues impacting commercialization?		
	• What are the opportunities to accelerate commercialization?		
4:30 p.m.	Adjourn		

Krynicky – August 16, 2021

Purpose:

Develop an integrated approach to the AMM qualification process for materials and components and identify current blind spots.

Objectives

- Understand current qualification processes
- Create novel approaches to process qualification
- Identify “what” industry needs in product, properties, and performance
- Identify areas in the AMM Supply Chain qualification that are lacking
- Identify possible synergistic qualification needs from industry through performance requirements
- Identify opportunities to shorten qualification by using AMM techniques
- Identify opportunities to reduce project cost by using AMM techniques

<https://gain.inl.gov/SitePages/Workshops.aspx>

139 Total Attendees
66.3% Engagement Ratio

“Current Standards for Materials and Component Qualification, and the Regulatory Process”

The following were suggested pathways for qualification of new alloys:

- To **gain experience** with the AM process (or other new AMMs),
 - utilities to insert components into “pressure retaining” operations within **secondary systems**.
 - experience could also be gained **via fossil or other systems**.
- AM components will be more difficult to inspect than conventional product forms: forgings, wrought, and powder metallurgy hot isostatic press (PM-HIP).
 - Industry focus on **developing new inspection methods** such as computer-aided tomography to assess thicker sections of AM products.
 - Development of an Acceptance Guideline for nondestructive examinations (NDE) was also suggested.
- ASME Div. 5 already provides an avenue to qualification—
 - user will submit data to a certain number of hours of operation, put a component in service using the material, and then continue to **develop data in parallel with the service operation**.
 - This approach would allow a user to gain service experience while maintaining safe operation within the bounds of the current test data and ASME acceptance of that material.

“Nuclear Industry / End User Feedback and AMM Needs”

- The following takeaways were identified:
 - Advanced reactor developers are interested in pursuing a wide range of AMM applications and demonstrations, but the **long-term benefit** must be realized.
 - The existing commercial fleet has seen two successful first-of-a-kind (FOAK) deployments in the fuel assembly space – more related deployments are in the pipeline (i.e., debris filters, tie plates).
 - Question posed to utilities: Can we **pursue AMM deployments on the secondary side** (i.e., pumps, valves, etc.)?
 - Utilities continue to rely upon cold spray as a reliable mitigation strategy.
- ***AMM will inevitably evolve faster than the regulatory framework making technology-agnostic guidance vital.***

Main feedback received after workshop:

- Participants found the workshop valuable
- Follow-up workshops on this topic need to continue sooner rather than later
- A face-to-face meeting for breakout sessions for futuristic views are preferred.

Defining a New Future!

GAIN – EPRI – NEI Workshop November 4, 2021

- **Purpose:**

To engage the nuclear industry in discussions on advanced manufacturing codes, standards, demonstrations, and advanced techniques to accelerate commercialization.

- **Objectives:**

- Understand applications of **machine learning and digital twin tools**, through collaboration with codes and standards entities
- Define “**uncertainty**,” including measurements for uncertainty and how it can be minimized
- Identify **cross-cutting demonstration** or benchmarking products or projects that are suitable for early adoption by industry

<https://gain.inl.gov/SitePages/Workshops.aspx>



GAIN-EPRI-NEI
Advanced Materials and Manufacturing Technologies
VIRTUAL PANEL SESSION: DEFINING A NEW FUTURE!

Virtual Workshop: November 4, 2021 | GAIN.INL.GOV



Agenda

Time (ET)	Description	Presenter / Moderator
11:00 a.m.	Welcome	Lori Braase, GAIN
11:05 a.m.	Welcome and AMMT Program Overview	Dirk Cairns-Gallimore, DOE-NE Meimei Li, AMMT NTD
11:15 a.m.	AMM Qualification Workshop Lessons Learned and AMMT Virtual Panel Session Objectives	Isabella van Rooyen, INL
11:30 a.m.	Presentation 1: ASME VVUQ – Activities to Support Machine Learning and Digital Twins	Josh Kaizer, US NRC
11:45 a.m.	Group Discussion	Ram Devanathan, PNNL
Noon	Presentation 2: ASME VVUQ – Activities to Formalize Uncertainty Quantification	Josh Kaizer, US NRC
12:15 p.m.	Group Discussion	Curtis Smith, INL
12:30 p.m.	Presentation 3: A Digital Twin for Part-A Acceptance and Related Efforts at NIST	Paul Witherell, NIST
12:45 p.m.	Group Discussion	Ryan Dehoff, ORNL
1:00 p.m.	<i>Break</i>	
1:15 p.m.	Industry Benchmarking Panel – Needs for Demonstration Components	Hilary Lane, NEI Isabella van Rooyen, INL
	Discussion may include:	Jurie van Wyk, Westinghouse Tim Bell, Siemens Timothy Lucas, X-energy Xuan Zhang, ANL Samuel Miller, TerraPower
	<ul style="list-style-type: none"> • Ceramics • Composites • In-core • Balance of Plant • Powder Mfg. • Etc. 	
2:45 p.m.	Path Forward	Dirk Cairns-Gallimore, DOE-NE
3:00 p.m.	<i>Adjourn</i>	

99 Total Attendees
69.7% Engagement Ratio

Machine Learning (ML) and Digital Twins (DT)

Moderator: Ram Devanathan, Ph.D. (PNNL)

- Josh Kaizer (US Nuclear Regulatory Commission): **“ASME Verification, Validation, and Uncertainty Quantification (VVUQ) –Activities to Support Machine Learning and Digital Twins.”**
 - Historical view of numerical modeling.
 - ASME VVUQ in Computational Modeling and Simulation Standards Committee
 - ✓ development of standards and procedures for assessing and quantifying the accuracy and credibility of computational models and simulations.
 - ✓ Timeline of ASME VVUQ subcommittees culminating in VVUQ70.
 - This subcommittee develops standards and procedures for machine learning algorithms applied to mechanistic and process modeling.
 - ✓ **Importance of defining consistent terminology.**
- Group discussion outcomes:
 - VVUQ activities can serve to increase the credibility and acceptance of ML.
 - Placing excessive emphasis on interpretability will prevent us from taking advantage of useful ML models. Such models can be verified using high fidelity data.
 - To increase adoption of ML and DT : **a role for centralized database for terminology and best practices**; not just for codes and standards.
 - It is **possible to use model-based engineering to ensure consistency**, but the details could not be fleshed out in the limited time available for the discussion.

Industry Benchmarking: Demonstration Components Needs

Moderators: Hilary Lane (NEI)

Isabella van Rooyen, Ph.D. (INL)

- Overview of advanced manufacturing (or advanced materials) for ongoing projects:
 - Jurie van Wyk (Westinghouse),
 - Tim Bell (Siemens),
 - Timothy Lucas (X-energy),
 - Xuan Zhang (ANL),
 - Samuel Miller (TerraPower).
- Moderated panel questions and Q&A from the audience:
 - Dr. Zhang provided a deeper dive into ANL's research which demonstrates that AM-produced pressure retaining components perform in line with conventionally-produced alloys.
 - Candidate pressure retaining components could include **pressure relief valves** (produced by DED).
 - Westinghouse is focused on ceramic matrix composites (CMC) needs,
 - ✓ Use of data from other industries for CMC safety components?
 - ✓ Candidate **CMC components** are being considered, such as in-core components and heat exchangers.
 - ✓ X-Energy is focused on graphite needs for candidate in-core components. However, only a **few select graphite suppliers** are qualified.
 - ✓ The need for accelerated qualification for both ceramics and graphite components was stressed, as was the difficulties and **challenges in "data sharing."** CRADAs were mentioned as one option for increased collaboration.
 - ✓ TerraPower identified that **DOE national labs** could play a role in R&D for irradiated fuel specimens, and that this could also help lower the cost for fuel qualification. Use of research reactors could also play a role.
 - ✓ For the current fleet or SMRs, more R&D is needed on **weld repair and coatings.**
 - ✓ Further, AM (i.e., **cold spray**) may be feasible for fuel claddings and/or coatings.

GEN IV International Forum (GIF)

Advanced Manufacturing and Materials Engineering-Task Force (AMME-TF)

MEMBER	COUNTRY
Eric Abonneau	FR
Davide Costa (technical secretary)	OECD/NEA
Lyndon Edwards (chair)	AU
Lucian Ivan	CA
Yu Kamiji	JP
Shehan Lowe	UK
Mark Messner (co-chair)	US
Karl-Fredrik Nilsson (task lead)	EU
Satoshi Okajima	JP
Jeong-Yong Park	KR
Manuel Pouchon	CH
Isabella van Rooyen (task lead)	US
Andrew Storer (task lead)	UK
Sebastien Teysseyre	CA
Kodai Toyota	JP
Lefu Zhang	CN

- Getting new materials or new manufacturing processes qualified for use in Nuclear Reactors can be a long and tortuous process.
- The long lead times involved produce an effective and consequent barrier to market entry of advanced materials and manufacturing processes.
- **Developments in advanced manufacturing are occurring much faster than our ability to introduce new materials and methods into nuclear design codes.**
- This is stifling innovation and hampering deployment and effectively results in a barrier to market entry.
- These issues need to be addressed if advanced reactors are to be brought to the market in reasonable timeframes.
- GIF AMME Task Force formed to assess and address these issues.

[Lyndon Edwards, Chair AMME-TF]

GIF-AMME-TF Activities



2019
Industry Survey

Feb 2020
Advanced
Manufacturing
workshop

2021
Revised TF
Terms of
Reference

April 2021
2nd Industry
Survey
(38)

Nov 2021
Modeling and
Simulation
Workshop

June 23, 2022
Qualification
Workshop

Oct 3-7, 2022
GEN IV
Industry Forum

- >70 Delegates
- Private Sector
- SMR vendors
- Suppliers
- Regulators
- Researchers

- Requirements Capture
- Qualification, Demonstration & Deployment
- Design and Modelling

- Very High Need:
- Reactor vessels & **internals** (42%)
 - **Heat transfer** (30%)
- Support efforts on:
- Codes & Standards
 - Regulatory approvals
- Materials Highest Priority:
- **SS 38%**
 - **Low Alloy Steel 24%**
 - Ni alloys 20%
 - **Ceramics & Fuel 16%**
 - Zr Alloys 2%
- AM techniques:
- **Adv welding processes**
 - PBF
 - DED
 - Coating deposition
 - PM-HIP
 - Cold/hot spray
- ↑ **Establishing & predicting material and product properties**

- Westinghouse (**David Huegel & Clint Armstrong**),
- Framatome (**Jean-Marie Hamy**),
- General Atomics (**George Jacobsen**),
- University of Pittsburgh (**Albert To**),
- CEA (**Pierre-François Giroux**)
- NRC (**Carolyn Fairbanks**)

M&S White Paper on
Collaboration Projects
(Oct 2022)

- Westinghouse (**Jurie van Wyk**),
- CEA (**Cecile Petesch**),
- NASA (**Richard Russel**)
- NRC (**Raj Iyengar**)

- Jointly with G4SR
- Joint AM workshop with CAMiNA (Oct 3)



https://www.gen-4.org/gif/jcms/c_115848/workshop-on-advanced-manufacturing
"GIFted" Your GIF Newsletter, Edition 10, Sept 2021 www.gen-4.org

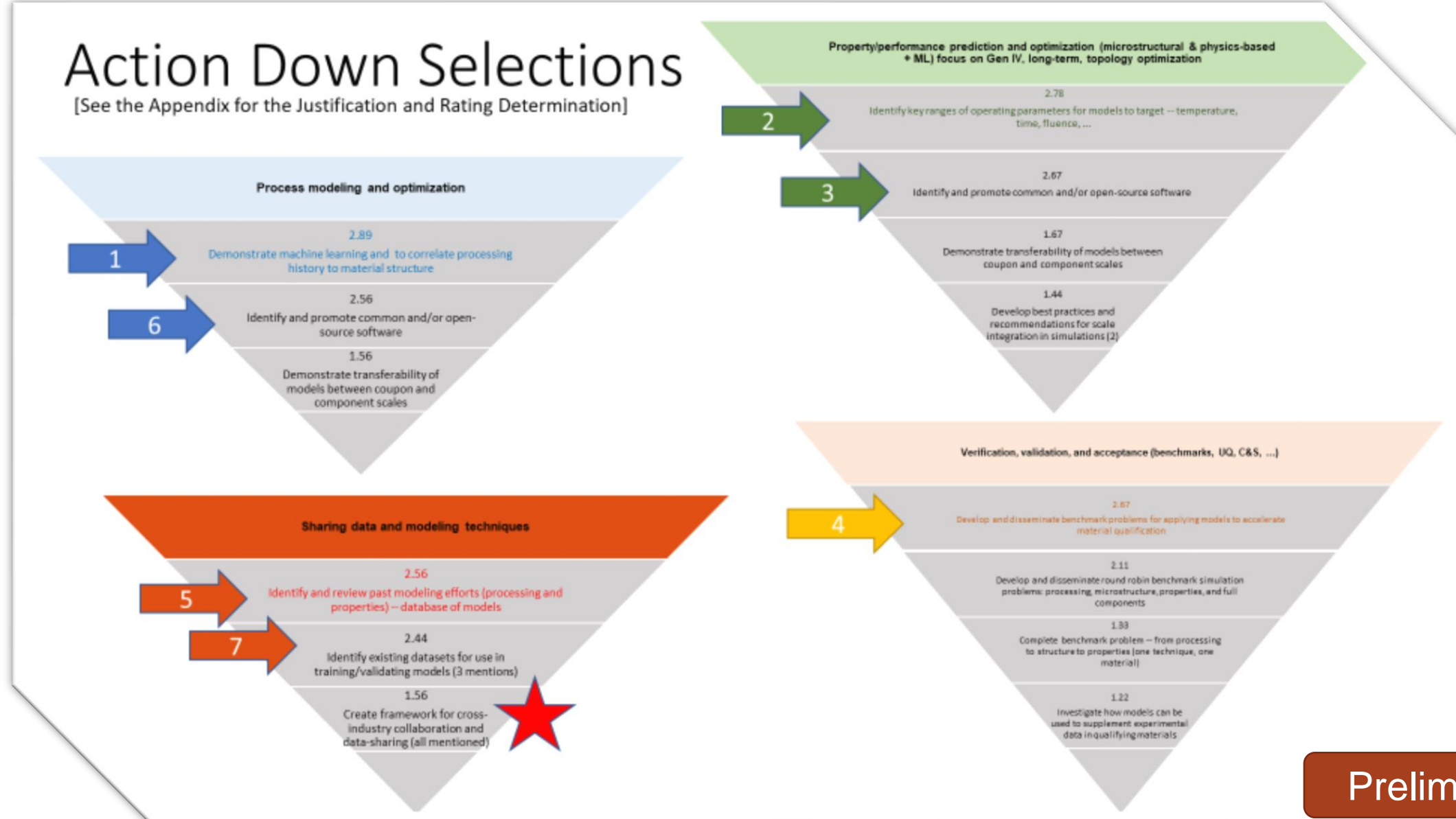


- Community has grown
- Community become more focused
- Interested in collaborating

Modeling and Simulation Workshop Outcome Summary

Action Down Selections

[See the Appendix for the Justification and Rating Determination]



Preliminary

Continued feedback is critical to accelerate the deployment of domestic and economically viable technologies to support the current fleet and new advanced reactor technologies.



Thank you

Acknowledgement

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