

## Advanced Manufacturing and Materials Engineering Task Force

Although some small modular reactors (SMRs) under development are based on simplified LWR technology, many are based on Generation-IV (Gen-IV) technology that utilizes the inherent safety capability arising from non-water-cooled reactors. A key to the successful mass deployment of the SMR approach is the assertion that the agile manufacturing of components and structures in factory-like environments enabled by large-scale production will substantially reduce the capital cost of new nuclear deployment. This reduction in capital cost requires innovation in the nuclear supply chain, particularly in the areas of advanced manufacturing and materials engineering, if they are to be delivered on time and on budget.

Nuclear design codes, however, typically dictate that only qualified materials and processes can be used, making qualification a potentially long and complicated process. Furthermore, developments in advanced manufacturing are occurring faster than our ability to introduce new materials and methods into design codes, potentially stifling innovation and hampering deployment.

The GIF Advanced Manufacturing Materials Engineering Task Force (AMME-TF) was formed to determine how collaborative R&D could be used to enable such advances so as to reduce the time to deployment of Gen-IV and comparable advanced reactors.

In 2019, the AMME-TF undertook a survey of advanced nuclear reactor vendors, supply chain specialists, regulators and other experts, discovering that most advanced manufacturing methods were considered opportunities by potential end users, and that 90% of respondents identified the greatest obstacle to their adoption as the creation and approval of the appropriate codes and standards.

In the first half of 2021, the task force undertook a second survey to investigate the “if and how” the community’s activities and opinions on these issues had changed. The survey was sent to nuclear reactor vendors, supply chain specialists, regulators, national laboratories and potential end users. The distribution list was created based on recommendations from GIF member country representatives and similar experts. The intent, as in 2019, was to gather the opinions of people actively engaged in the design and manufacturing of advanced nuclear reactors. The size of the distribution list had doubled since 2019, providing further anecdotal evidence that the community working on the manufacturing

and deployment of advanced reactors has continued to grow. Consequently, the number of survey responses also increased concomitantly. Replies were nearly equally divided from North America, Asia and Europe.

Turning to the survey itself, it is interesting to compare the responses from the 2019 survey to the 2021 survey. Overall, active interest in advanced manufacturing has expanded, with significant increases in reported efforts to support codes and standards and to secure regulatory approval, and with a substantial decrease in the number of respondents taking an interest, but adopting a “wait and see” attitude.

Regarding the application of advanced manufacturing, a change in the focus has been observed in terms of the reactor components being considered for advanced manufacturing, with an increase in interest in relation to reactor internals and heat transfer infrastructure (e.g. pipes, valves and heat exchangers) and a decrease in interest in relation to reactor vessels, fuel cladding and fuel assemblies. There was also an increased focus on the advanced manufacturing of traditional nuclear materials, with most efforts concentrated on stainless steels, low alloy steels and nickel alloys.

Overall, the results from the second survey in 2021 showed that both the size and the interest of the community had grown and become more focused. In addition, the community’s focus on qualification, and modeling and simulation as a potential enabler for the qualification of advanced manufacturing and materials, was confirmed. Indeed, enthusiasm for engagement with the task force has also grown, with 54% of respondents reporting a *high* or *very high* interest in the idea of holding a workshop on modeling and simulation and 84% reporting a *high* or *very high* interest in holding a workshop on qualification.

In February 2020, before the COVID-19 pandemic began, the task force held an international workshop at the Nuclear Energy Agency (NEA) headquarters in Paris designed to investigate how collaborative R&D in the field of advanced manufacturing can be used to reduce the time to deployment of advanced reactor systems.

Details of the workshop, which was attended by over 70 representatives from conventional and SMR vendors, nuclear supply chain suppliers, regulators and researchers, can be found on the GIF website.<sup>1</sup>

1. See: [www.gen-4.org/gif/jcms/c\\_115848/workshop-on-advanced-manufacturing](http://www.gen-4.org/gif/jcms/c_115848/workshop-on-advanced-manufacturing).

The recommendation of the workshop was that collaborative activities should be actively encouraged in the following areas:

- qualification: including new modalities (e.g. real time process qualification);
- design and modeling: including the sharing of data for design optimization and modeling and simulation benchmarks.

The task force has thus developed an integrated plan for a series of workshops on both qualification and how modeling and simulation can be used to accelerate qualification. Since the outputs of a modeling and simulation workshop were perceived as representing a key input into a qualification workshop, it was decided to hold modeling and simulation workshop first on 8-9 November 2021.

The focus of the 2021 workshop was on how modeling and simulation can enable the qualification of advanced manufacturing. As was the case during the 2020 workshop, this virtual workshop contained several interactive small group sessions with peers, where attendees were asked to discuss and assess options and opportunities for the qualification of advanced manufacturing. Details of the workshop can be found on the GIF website,<sup>2</sup> and the workshop structure is shown in Figure AMME-1.

Session 1 of the workshop provided an overview of the potential for modeling and simulation to support the nuclear qualification of advanced manufacturing from both researcher and regulator’s perspectives while session 2 showcased the activities of advanced reactor vendors and designers. Both sessions were designed to stimulate discussion among workshop attendees, with most of the time allocated to group sessions. In session 3, attendees were allocated to groups, and asked to discuss and identify opportunities for modeling and simulation that would help to accelerate qualification of advanced manufacturing. They were, then asked to prioritize, by likelihood of success, the best opportunities for deployment. The outputs of each of these deliberations were presented to the entire workshop during session 4, entitled “Comparing Group Outputs”.

Some common themes emerged from the group presentations, enabling a number of distinct opportunities to be identified as areas for further analysis, and these include:

- collaborative modeling and simulation R&D to control the process (process qualification and quality assurance);
- collaborative modeling and simulation R&D to predict the microstructure and/or the material/component properties (enabling component design code compliance);
- collaborative R&D where modeling and simulation models, software and data are “shared” (including the idea of an advanced material property database);
- collaborative modeling and simulation R&D focused on codes and standards.

The task force is currently undertaking a detailed examination of the ideas and comments from the workshop and will present the full outcomes in 2022.

**Figure AMME-1: Content and methodology of the AMME-TF Modelling and Simulation Workshop, 8-9 November 2021**

*AMME Workshop on Advanced Manufacturing (Virtual) Nov 2021, OECD, Paris, France*

Mon 8 Nov		GIF AMME Workshop on Advanced Manufacturing DAY 1
<b>Session 1 – Overview of workshop</b>		
13:00 – 13:10	Welcome and Introduction, overview of AMME-TF, purpose of workshop!	<i>Lyndon Edwards</i> ANSTO, AMME-TF Chair
13:10- 13:35	How Modelling and Simulation could be used to support the nuclear qualification of advanced manufacturing	<i>Albert To</i> , University of Pittsburgh (20mins+5 min questions)
13:35 - 14:00	Challenges to the use of M&S to support the nuclear qualification of advanced manufacturing: a nuclear engineer’s perspective	<i>Pierre-François Giroux</i> , CEA (20mins+5 min questions)
14:00 – 14:25	NRC Action Plan for Advanced Manufacturing Technologies	<i>Carolyn Fairbanks</i> , NRC (20mins+5 min questions)
<b>Session 2 – Vendors and designers perspective: the view from the innovation front line</b>		
14:30 - 14:50		<i>David Huegel &amp; Clint Armstrong</i> , Westinghouse (15mins+5min questions)
14:50– 15:10		<i>Jean-Marie Hamy</i> , Framatome (15mins+5min questions)
15:10– 15:30		<i>George Jacobsen</i> , General Atomics (15mins+5min questions)
15:30– 16:00	Summary, Panel Discussion and Group Activity Briefing	
<b>Session 3 – Group activity 1</b>		
16:00 – 17:30	Attendees split into allocated groups, which undertake the following activities with the group Moderator/Rapporteur:	<ul style="list-style-type: none"> <li>a. Discuss and identify opportunities for Modelling &amp; Simulation to accelerate qualification of Advanced Manufacturing</li> <li>b. Analyse each identified opportunity (SWOT analysis or similar)</li> <li>c. Prioritise, by likelihood of success, best opportunities for 2030 deployment</li> <li>d. Agree communication for Rapporteur to give to meeting at start of Day 2 (Can develop presentation overnight if necessary)</li> </ul>
<b>Includes break as necessary</b>		
17:30	End of Day 1	
<b>Tue 9 Nov</b>		
<b>GIF AMME Workshop on Advanced Manufacturing DAY 2</b>		
<b>Session 4 – Comparing Group Outputs</b>		
13:00 – 14:15	Whole workshop undertakes the following activities:	
	<ul style="list-style-type: none"> <li>a. Rapporteurs from each group presents group output (5 x 10 minutes)</li> <li>b. List agreed areas to be addressed and potential collaborative opportunities</li> </ul>	
14:15 – 14:45	Break	
<b>Session 5 – Group Activity 2</b>		
14:45 – 16:00	Attendees split into new opportunity specific groups (those identified as having highest priority) and undertake the following activities:	
	<ul style="list-style-type: none"> <li>a. What needs to be done</li> <li>b. How can collaboration help?</li> <li>c. Identify and prioritize areas/ideas for AMME activities/projects</li> <li>d. Agree communication for Rapporteur to give to meeting after break</li> </ul>	
16:00 – 16:20	Break	
<b>Session 6 – Final Group Reporting and Meeting Outcomes</b>		
16:20- 17:30	Each Group present their findings and recommendations	
17:30 – 18:00	Summarise findings and consensus of meeting	
18:00	End of Meeting	



**Lyndon Edwards**  
Chair of the AMME TF,  
with contributions from  
AMME members

2 See: [www.gen-4.org/gif/jcms/c\\_82829/workshops](http://www.gen-4.org/gif/jcms/c_82829/workshops).