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SIMULATION INFORMED MICROSTRUCTURE AND PROPERTIES TAILORING

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ABSTRACT

Additive manufacturing creates an opportunity to tailor material performance through process design, yet establishing reliable links between process settings, thermal history, microstructure and properties remains a challenge. These links span melt-pool and solidification phenomena, grain and phase evolution, defects, residual stresses and mechanical response. The chain spans scales and varies with alloy, geometry, build history and manufacturing route.

This invited session will bring together perspectives on how simulation is advancing understanding of these relationships and supporting microstructure and property control. Contributions will consider models of heat flow, fluid motion, powder or wire feedstock and solidification; prediction of microstructure morphology, texture and defects; and the transfer of simulated structures into models of deformation and performance. They will examine how process parameters and strategies, including scan paths, layer conditions, beam profiles and energy delivery, can be selected to influence material outcomes, and where characterisation and in-situ data can test those predictions.

The discussion will include powder bed fusion, directed energy deposition, wire arc additive manufacturing, and related processes. Differences in heat sources, deposition modes and thermal cycles raise a question: which modelling concepts and predictive tools can be shared across processes, and where must models reflect process-specific physics? Recent progress in high-fidelity process modelling, scalable microstructure simulation, data-driven methods and experimental validation creates new opportunities, while also highlighting limits in computational cost, available data, uncertainty quantification, model credibility and transferability.

The session will invite speakers and participants to consider what is now predictable, what evidence is needed before simulations can guide manufacturing decisions, and how process, material and component design can be connected. The goal is a discussion of the advances, unresolved challenges and research priorities needed to move from explaining manufactured microstructures toward using simulation to select processing routes for required properties and component performance.