

***MULTI-FIDELITY DIGITAL TWINS:
THEORY, SCALABILITY, AND AI-DRIVEN DESIGN***

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ABSTRACT

The realization of a functional Digital Twin (DT) hinges on resolving the fundamental conflict between physical rigor and real-time responsiveness. While high-fidelity simulations provide necessary precision, their prohibitive computational costs often preclude real-time synchronization with physical assets. Conversely, simplified models or purely data-driven approaches often lack physical consistency and predictive reliability in unobserved regimes. To bridge this gap, Multi-Fidelity (MF) modeling [1] has emerged as a critical enabler. By strategically integrating diverse information sources—ranging from multi-physics simulations and experimental data to real-time sensors and expert knowledge—MF approaches offer a robust framework to balance accuracy with computational efficiency, particularly as industries transition toward large-scale and safety-critical digital twin ecosystems.

This session aims to move beyond simple error correction, focusing on how MF frameworks can enhance and deepen information to transform disparate data into actionable insights for high-stakes decision-making. We invite contributions that address the core engineering requirements of modern DTs, including scalable mathematical structures that facilitate hierarchical fusion.

Furthermore, we seek innovative research on rigorous uncertainty quantification across fidelity layers, the hybrid integration of deductive physical laws with inductive observation data, and emerging AI-driven approaches, including agent-assisted modeling and autonomous workflow coordination, within unified probabilistic environments. We also welcome studies on the strategic application of these models to data-driven optimization, robust design, and efficient decision-making under uncertainty. By exploring these theoretical foundations and practical implementations across fields such as aerospace, infrastructure, and energy, this session seeks to define the next generation of reliable, scalable, and design-ready digital twins.

REFERENCES

- [1] Peherstorfer, B., Willcox, K., and Gunzburger, M., *Survey of multifidelity methods in uncertainty propagation, inference, and optimization*, SIAM review, 60(3), pp. 550–591, 2018.