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SCIENTIFIC MACHINE LEARNING FOR DIGITAL TWINS IN ENGINEERING

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ABSTRACT

Deploying digital twins in practice requires models that can run fast enough to be useful, update as new data arrives, and produce predictions that engineers can trust. Physics-based simulations rarely meet all three criteria on their own, and black-box machine learning models often fail the moment conditions shift outside the training set. Scientific machine learning addresses this gap by building physical knowledge directly into the learning process — not as a post-hoc correction, but as a structural constraint.

This minisymposium focuses on SciML methods that work in the context of live, operational digital twins — not just offline surrogate training. We are particularly interested in contributions that deal with what happens after the model is built: keeping it synchronized with a real system, handling sensor noise and missing data, and knowing when its predictions can be trusted. Contributions are invited on:

- Physics-informed neural networks, neural operators, and equation-informed learning architectures
- Hybrid and multi-fidelity model architectures
- Reduced order models combined with or enhanced by machine learning
- Data assimilation and model updating for real-time synchronization
- State estimation under noisy or incomplete observations
- Uncertainty quantification and prediction reliability
- Graph-based and topology-aware learning for spatially distributed systems
- Applications across structural, mechanical, aerospace, energy, and manufacturing domains

The session welcomes both methodological contributions and case studies from real engineering problems. By bringing together researchers from nonlinear dynamics, computational science, and machine learning, this minisymposium aims to accelerate the development of SciML methods that are robust, efficient, and impactful for twinning practice.