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FREDA: A Multi-Fidelity Plasma-Engineering Integrated Modeling Platform for Fusion Reactor Design and Assessment

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Integrated modeling of fusion reactor design is essential for predicting self-consistent multi-physics loads (thermal, electromagnetic, plasma, neutron, etc.), assessing technical feasibility, quantifying uncertainties, and enabling design trade-off studies to de risk FPP concepts and guide meaningful validation experiments. The Fusion REactor Design and Assessment (FREDA) SciDAC project is developing a flexible component-based integrated plasma and engineering modeling framework to support end-to-end, multi-fidelity reactor design workflows.

FREDA combines theory-based physics and engineering models from both the fusion and fission communities for self-consistent, iterative assessment and optimization. The framework builds on the IPS-FASTRAN plasma simulation backbone, incorporating newly coupled Core/Edge Pedestal/Scrape-Off-Layer models for predictive plasma performance and self-consistent wall and divertor heat and particle loads from charged particles, neutrals, and photons. FREDA also includes the FERMI suite of multiphysics engineering analyses (structural mechanics, thermal hydraulics, computational fluid dynamics, electromagnetics, and nuclear performance) to evaluate components such as the first wall, blanket, and magnets. Parametric CAD representation is generated with a newly developed TRACER tool, and a new AI/ML divertor meshing capability enables scans in geometry and operational constraints. Example workflows will be shared.

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