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**High-Fidelity Simulations of Multiphysics Systems**

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A pacing theme in the high-fidelity simulations of multi-physics flows is the continual push towards constitutive models that reflect the underlying physics more closely than ever before. At the same time, to impact the design and understanding of real fluidic devices, these models must ultimately be developed in the setting of a highly flexible computational infrastructure capable of both massive parallelism and geometric flexibility. This theme is illustrated using two multi-physics simulations that provide new incite into the behavior of complex fluidic devices. In the first, a novel unstructured Volume-of-Fluid (VoF) method is applied to simulate the liquid fuel atomization processes in a complex high shear nozzle typical of realistic gas turbine injectors. The simulation make aggressive use of directional grid adaptation to support the local resolution of critical instability mechanisms associated with the atomization process. In a companion example, the prediction of flow field and noise in a subsonic jet is linked critically to modeling and resolution of the nozzle boundary layers.