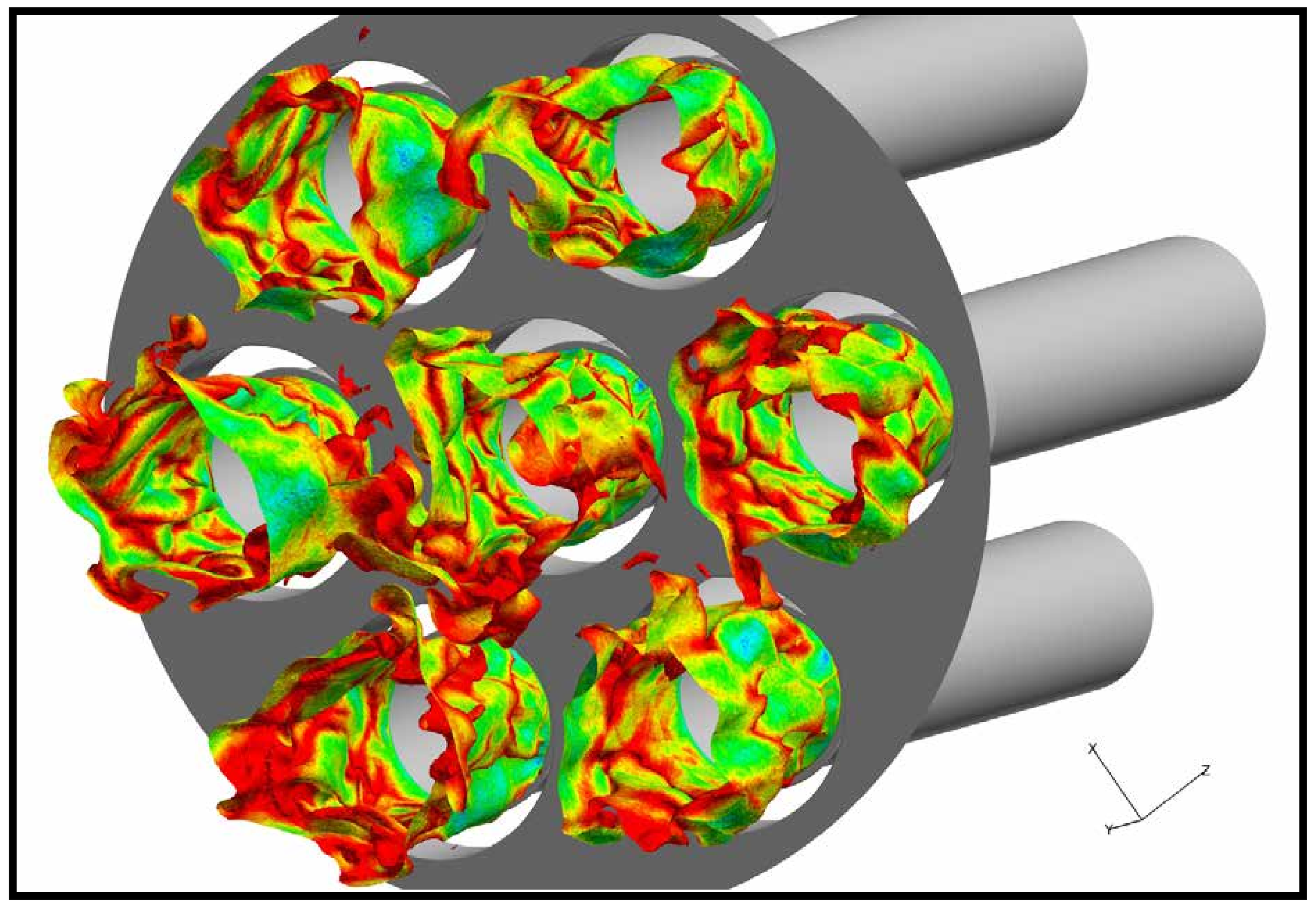
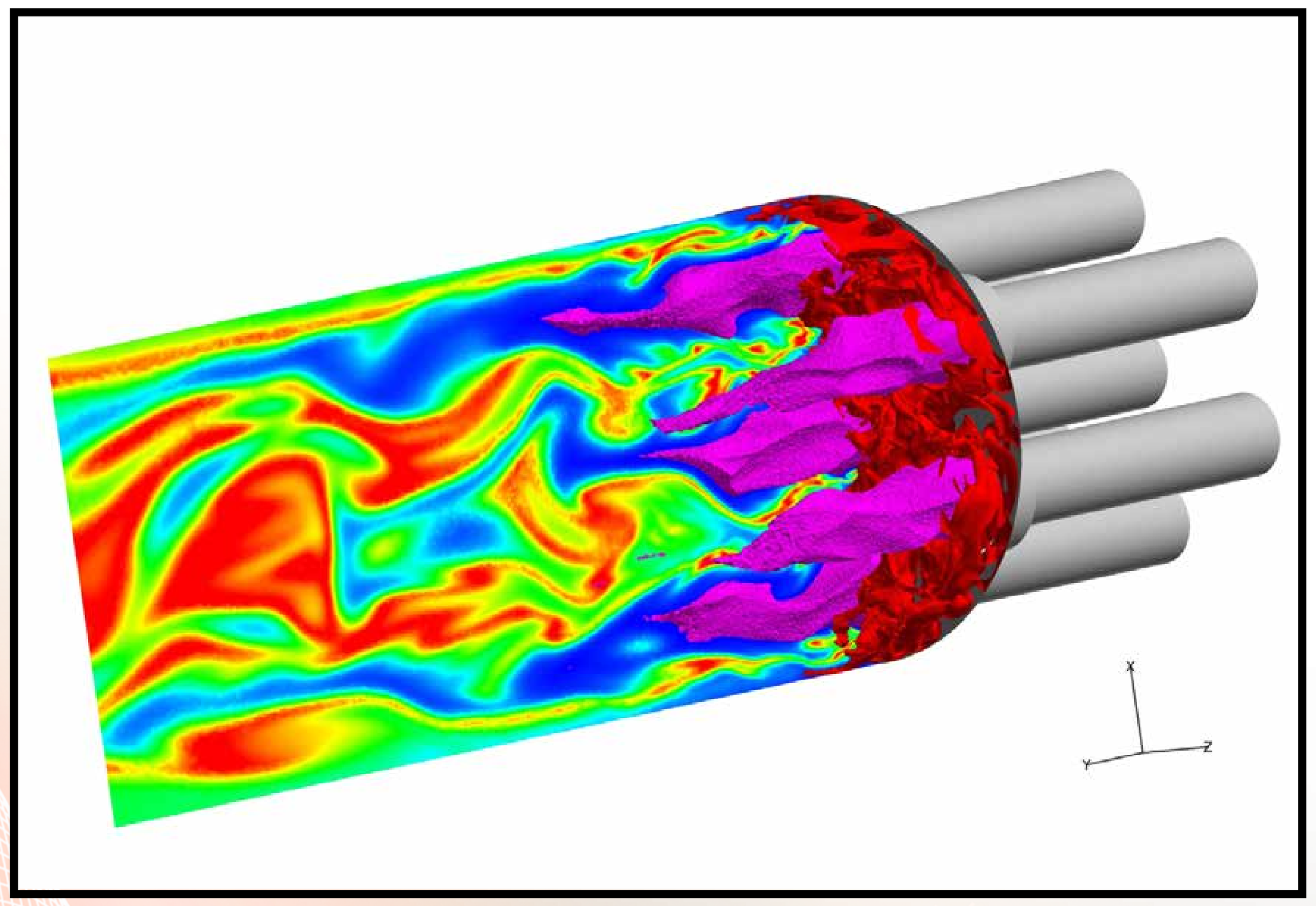
Designing Liquid Rocket Engine Injectors for Performance, Stability, and Cost



A snapshot of temperature contours during the combustion process in the rocket engine's combustor, just downstream of the injectors. These isosurfaces represent the instantaneous location of the unsteady flame-front originating from each injector element.
Brian Richardson, Douglas Westra, NASA/Marshall



Instantaneous CFD simulation result showing isosurfaces of the fuel (red) and oxygen (magenta) entering the combustion chamber, with red representing 100% fuel and magenta representing 100% oxygen. The fuel and oxidizer mix and burn, releasing combustion products downstream of the injectors. Further downstream, the contour plot shows the mass fraction of the combustion products.
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NASA is using computational fluid dynamics (CFD) simulations to lower the cost and increase the performance and stability of fuel injector designs for next-generation liquid rocket engines (LREs). The Loci-STREAM CFD code is used to simulate the complex combustion processes inside the LRE. These analyses enable efficient evaluation of the performance and stability characteristics of injector design concepts, while decreasing reliance on the costly test-fail-fix cycle of traditional design approaches. These injector simulations were recently employed as a key part of the design process for an Advanced Booster concept for NASA's heavy-lift Space Launch System (SLS).

- CFD simulations of one element and then seven elements of an oxygen-RP-based LRE injector concept were conducted to iteratively fine-tune the design's performance and stability characteristics.
- These CFD analyses provided greater amounts of higher-fidelity data than would have been possible using sub-scale hot fire tests.
- The primary result was a stable injector design that meets packaging requirements, pressure budgets, and engine efficiency requirements.
- This effort represents NASA Marshall Space Flight Center's most extensive use to-date of high-fidelity CFD to augment and improve the injector design process.

The CFD simulations performed were a critical part of the SLS Advanced Booster design cycle, where multiple design iterations were required relatively quickly. The simulations required long run times and large computational meshes on the order of 100 – 350 million cells. Access to the Pleiades supercomputer was a game-changer for this effort, enabling large-scale simulations to be routinely executed in less than two weeks using up to 4,000 processors per run. This remarkably quick turnaround time demonstrates the great potential of CFD simulations to help NASA reduce the cost of access to space by reducing reliance on expensive testing.

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