The Future of Rocket Engine Design

Rocket engine development continues to be driven by the intuition and experience of designers, progressing through extensive trial-and-error test campaigns. Extreme temperatures and pressures frustrate direct observation, and simulation is limited by:

- Turbulent scale separation of up to 8 orders of magnitude
- Small scale mixing driving combustion
- High per-node-cost of chemistry and real-gas properties

Within engines, the highly nonlinear physics at the smallest scales is crucial for capturing the large scale dynamics which characterize stability and performance. The development of high fidelity, high performance, sparse-data simulation can reduce the need for costly stand testing.

Adaptive wavelet collocation [1] is a high order finite-difference framework for solving PDEs on an optimal, dynamic grid. It uses multiresolution analysis to identify coherent structures and maintain a sparse-data representation.

Adaptive wavelet compression is particularly beneficial for turbulence simulation:

- Exploits intermittency
- Identifies most coherent structures for improved LES performance

For predictive simulation, high fidelity thermo-chemical property models are included. By implementing a sparse-data representation, the very high cost is mitigated by drastically reducing the number of nodes, enabling:

- Finite-rate kinetics
- Temperature-dependent and real-gas properties
- Highly accurate, optimized methane-oxygen reaction mechanism [3]

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