A New Capability for Highly Resolved Simulations

Isotropic adaptive mesh refinement is a method of dynamically adjusting the local resolution of a simulation. This allows highly accurate modeling of fine features in complex systems without a corresponding explosion in computational costs. Adaptive mesh refinement has now been implemented in the FLAG multi-physics ASC code. This is the first time such a capability has been available in an unstructured polyhedral arbitrary Lagrangian-Eulerian code.

The new mesh refinement capability will allow important advances for many national security applications. Examples include high explosive reactive burn; localization of plasticity, damage and failure in solids; hydrodynamic shocks; and contact discontinuities (material interfaces). Traditional approaches require that the entire domain be refined to the finest required resolution, but this approach does not scale well, particularly in 3D. Furthermore, this approach tends to be more accurate because it decreases numerical dissipation compared to Eulerian methods. The figures below illustrate some of the first results from applying adaptive mesh refinement in the FLAG code.

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Adaptive Scale-Bridging Model for Three-Dimensional Simulations of Energetic Systems

The success of predictive simulations for national security can often depend on accurately modeling the highly chaotic mixing process of turbulence that arises in sufficiently energetic hydrodynamic flows. This is a very hard problem that has been worked on by generations of great physicists and mathematicians. The traditional workhorse has been an approximation called the Reynolds-averaged Navier-Stokes, resulting in the RANS family of models of which LANL’s flagship turbulence model, BHR3, is one example. This method assumes that the flow can be described as the combination of an average flow, which captures smooth hydrodynamics, and a fluctuating flow, to model the range of unpredictable turbulent scales of motion. While the RANS approach has been successfully applied in many cases, it is also known to perform poorly in important 3-dimensional flow contexts, such as ignition capsules.

In recent years, better computing power has allowed for methods that resolve more of the turbulent scales to improve accuracy. However, these are very expensive and intractable for studies of engineered systems. To make these approaches useful, they have been combined with the traditional Reynolds-averaged algorithms, striking a balance between accuracy and affordability, in a new type of hybrid model that we call Dynamic BHR3.

Dynamic BHR3 has now been implemented, tested, and released in the ASC FLAG code. A canonical test case for turbulence models is the 3D Taylor-Green configuration for a decaying vortex, visualized in the figure below at a time after transition to turbulence. The complexity of the flow is evident and highlights the ability of the model to dynamically and locally blend between resolved and modeled calculations. This new turbulence modeling approach has been shown to better model such transitional flows, and reduce the computational cost for high fidelity simulations. This new approach has great potential to extend the validity of ASC codes for predictions of national security systems.

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NUCLEAR WEAPONS SAFETY

Upgrades to LANL’s Rapid Iterative Feedback Tool Increase its Speed, Accuracy, and Usability

An ability to quickly address concerns about consequences of high explosive detonation is a principal challenge for the weapon safety community. Answering questions from a production facility commonly requires executing dozens of large 3D simulations. Thanks to ASC codes and high-performance computers, these simulations can now be completed in times as short as a few days.

Safety simulations generate terabytes of complex data that need to be evaluated by experts. To speed up and improve the accuracy of this analysis, Los Alamos has developed the Rapid Iterative Feedback Tool (or RIFT). This capability assists safety modelers with the task of comparing simulation results with experimental results, such as for the Cyclops experiment shown in the figure at right.

Significant improvements have been made to RIFT over the last year. Better algorithms have increased its speed and accuracy for edge detection and overlays. Memory balancing has increased the speed when running in parallel across multiple processors. The GUI itself has also been improved with overlay features to allow custom transparency values and color palettes. Through improvements like these the RIFT is becoming an essential tool for the workflow within the safety community.

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