**High-Order Finite Elements Improve Lagrangian Hydrodynamics Simulations**

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Multi-physics simulation challenges

Next-generation numerical algorithms are needed to enable higher-quality computational multi-physics simulations.

In the absence of underground nuclear testing, computer simulation has become a cornerstone of the stockpile stewardship effort. Reliable shock hydrodynamics simulations are of critical importance to the NNSA simulation code efforts and applications such as the National Ignition Facility (NIF). Current Lagrangian hydrodynamics algorithms have a number of long-standing numerical issues that can reduce the predictive capabilities of our large-scale multi-physics codes, including:

- Lack of symmetry preservation and total energy conservation, the handling of artificial viscosity in multiple dimensions, and the presence of hourglass instabilities leading to mesh tangling.
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**A new computational approach**

We are developing a general high-order curvilinear finite element framework for Lagrangian hydrodynamics.

To address the above deficiencies, we are developing new numerical methods for Lagrangian hydrodynamics based on high-order finite element field representations, curvilinear zone geometries, tensor artificial viscosity, and high-order time stepping algorithms. Although this approach can be viewed as a high-order generalization of current methods, it has a number of advantages over them, such as increased accuracy and robustness on unstructured grids and significant improvement in symmetry preservation.

**Promising numerical results**

Our numerical methods have a number of practical advantages over traditional algorithms.

The new discretization methods were implemented in the recently developed research code BLAST, http://www.llnl.gov/casc/blast. The results from an extensive set of 2D and axisymmetric test problems demonstrate a number of practical advantages, including:

- Exact total energy conservation by construction, significant reduction in mesh imprinting, increased robustness and symmetry preservation on unstructured and distorted grids, and the ability to resolve shocks and thermodynamics gradients within a zone.

**Why is this important for our nation?**

High-order finite elements are a promising new technology for next-generation simulation capabilities.

Computer simulations are proving essential for stockpile stewardship. The technology developed in this research project has overcome a number of long-standing numerical challenges that are limiting the currently used simulation algorithms. The improved accuracy and robustness lead the way to increased predictive capabilities and to more reliable inertial confinement fusion (ICF) simulations in current and future exascale simulation codes.