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IMPROVED 2D TO 3D SIMULATION STRATEGY FOR INERTIAL CONFINEMENT FUSION CAPSULES

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We present a new method for performing 2D to 3D ICF capsule simulations [1]. This method involves perturbing the 2D to 3D mapping in order to compensate for the artificial smoothing effects of the rotation as well as the absence of vortex–stretching effects during the 2D phase of the simulation. We validate the method by performing it on a laser-driven reshock experiment [2], for which we have fully 3D simulation data for comparison [3, 4]. We show that, even after applying initial interface perturbations in 2D that are exaggerated beyond the point at which they can be considered physically reasonable, after rotating the simulation to 3D, one cannot generate nearly as much turbulence nor turbulent mixing as observed in the fully 3D simulations. If, however, perturbations are applied at the time of rotation to 3D, one can obtain good agreement with the purely 3D simulation data. In particular, good comparisons are obtained for various integrated flow quantities, including turbulent kinetic energy and an integrated mixing measure, as well as for the vorticity content of the flow.

Due to a lack of high-quality experimental data in relevant high energy density regimes, it is important to find ways of validating our predictive capabilities beyond comparison to experiment. Due to high sensitivities to target imperfections in the available experimental data, direct comparisons of simulation and experimental radiographic data are insufficient for validation of our simulation strategies. Therefore, we supplement these comparisons by performing spectral analysis. In addition, we compare statistics of the data to results from direct numerical simulation and the theory of homogeneous isotropic turbulence. Our results show that in shock-driven transitional flows, some turbulent features, such as self-similarity and isotropy, only fully develop once others have decayed significantly.

We perform our new 2D to 3D simulation strategy on a simple OMEGA–type ICF capsule. Our results are in good agreement with all available experimental data and suggest that the primary mechanism for yield degradation in ICF capsules is turbulent material mixing seeded by long–wavelength surface defects, compounded by shorter wavelength drive

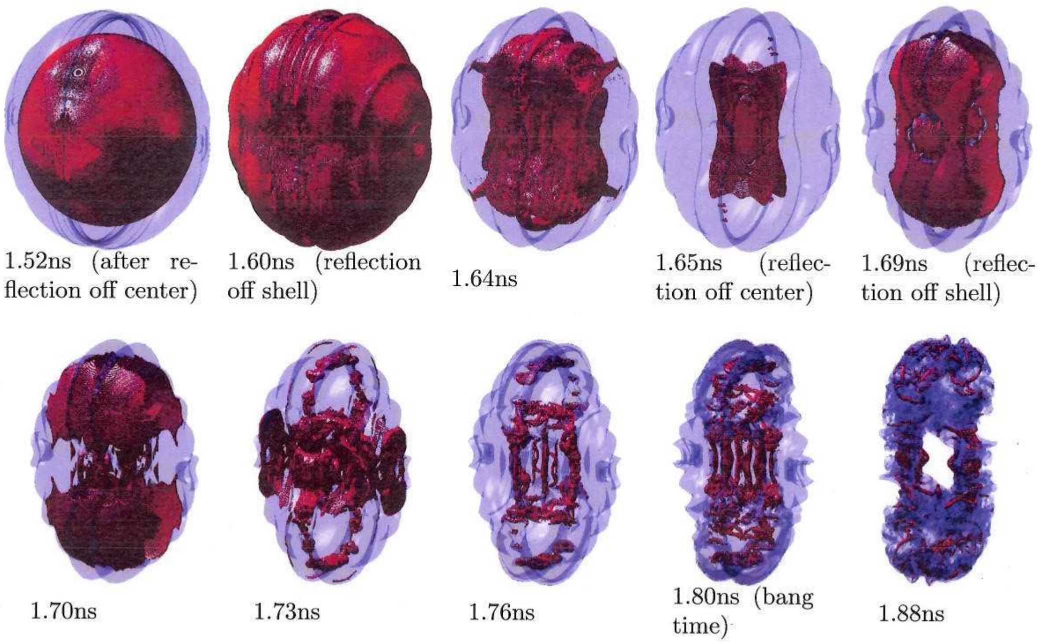

Figure 1: Visualization of the main shock (in red) and its interactions with the fuel/gas interface (in blue) for an OMEGA-type ICF capsule.

asymmetries. Distortions in the capsule shape break up the main shock into many smaller shocks (see Fig. 1) traveling in all directions, which proceed to have many interactions with fuel/shell interfaces, inducing Richtmyer–Meshkov instabilities at each interaction. The growth of these instabilities mixes shell material into the fuel and tears the capsule apart, quenching the thermonuclear burn.

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