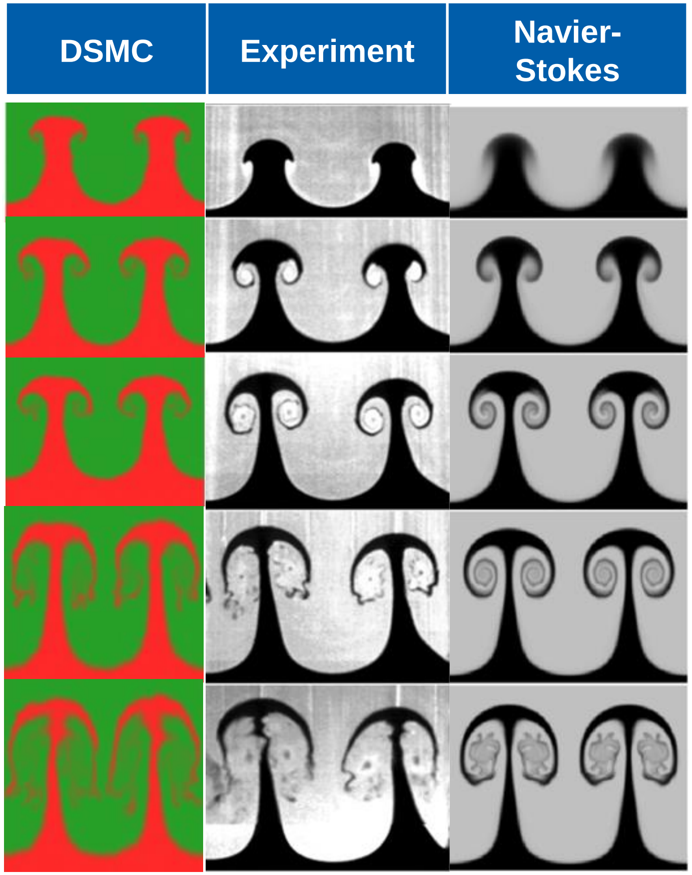
DSMC simulations of hydrodynamic instabilities

SAND2014-16900PE
Tracking# (SAND, PR) ____________

- The Richtmyer-Meshkov Instability (RMI) appears in Inertial Confinement Fusion (ICF), interaction of shocks with flames
- RMI provides an extreme test of the hydrodynamics for molecular gas dynamics
- RMI simulations at the molecular level were performed using SPARTA, a new 3D DSMC (Direct Simulation Monte Carlo) code
- DSMC provides a molecular-level description of the hydrodynamic processes, that may be physically more realistic for strong shocks, chemically reacting flows

Principal Investigator: Michael A. Gallis
Platform/Campaign: Sequoia CCC-6
Usage: 17 days (170% of Allocation)



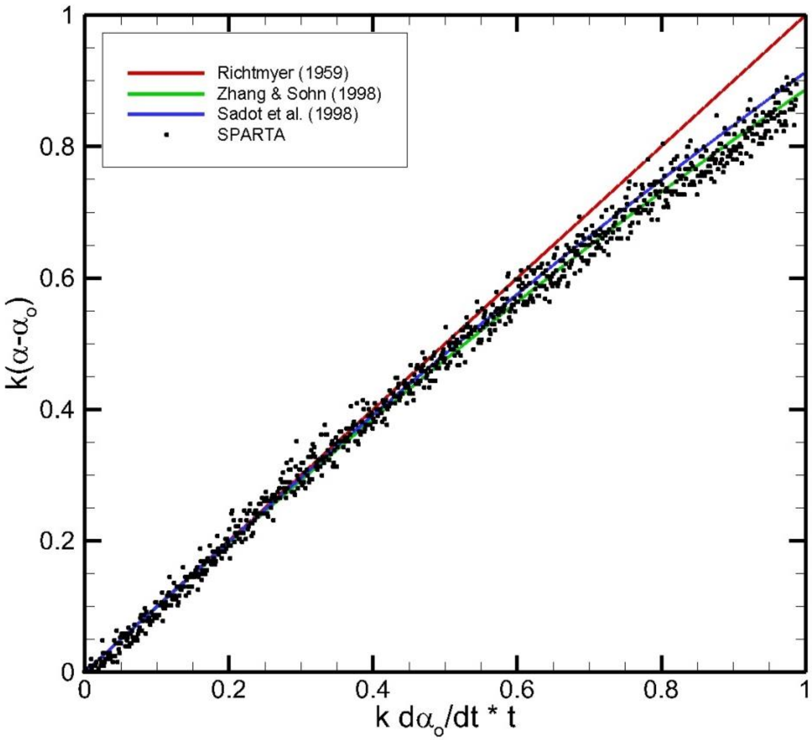
Richtmyer-Meshkov Instability in Air-SF_6. Comparison between DSMC, Navier-Stokes and experiment

Tracking# (SAND, PR) ____________

DSMC simulations of hydrodynamic instabilities

- Sequoia enabled the first-ever DSMC simulation of RMI in real gases
- A 24hr simulation using 98,304 nodes (1.57 mil cores) was used in this study
- DSMC simulations provide predictions for the growth rate of the instability in very good agreement with theoretical and empirical models
- These comparisons indicate that molecular-level processes may be able to provide useful insight to fundamental hydrodynamic problems
- These results were announced in a keynote lecture at the 29th Rarefied Gas Dynamics Symposium

DSMC Simulation of RMI initial growth rate



Non-dimensional amplitude for an initial small amplitude perturbation compared to theoretical, empirical results.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Sandia National Laboratories

Tracking# (SAND, PR) ____________

DSMC simulations of hydrodynamic instabilities

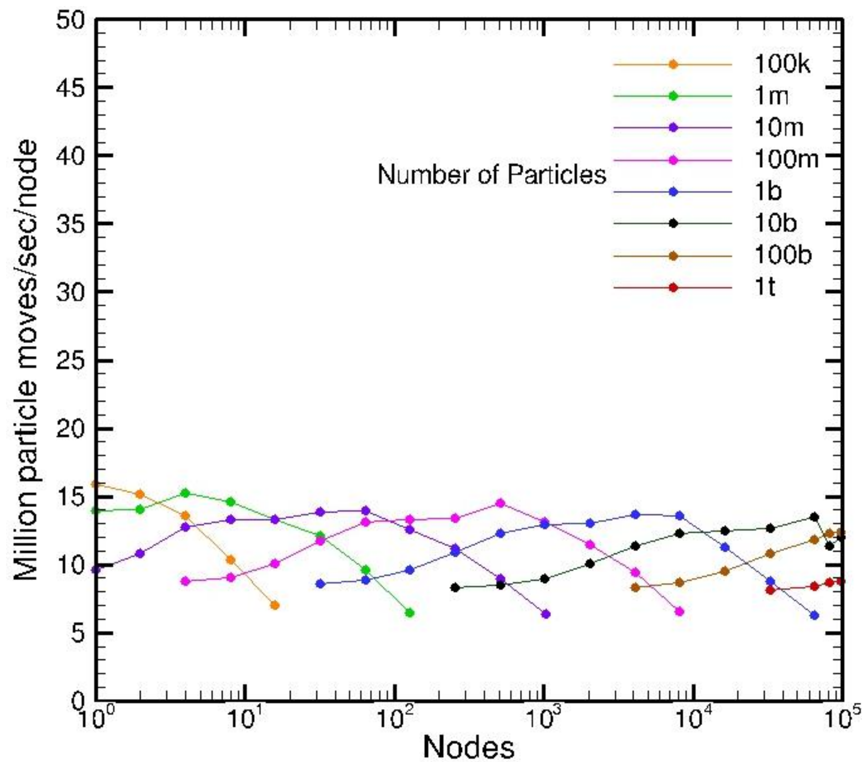
U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

Performance of SPARTA on Sequoia

- SPARTA is able to take advantage of 100% of Sequoia
- Through hyper-threading, up to 4 MPI-tasks per core were utilized, while each node employed 16 cores
- The maximum number of particles and cells that can be simulated on Sequoia was 3 trillion and 1 trillion respectively
- Meaningful simulations were performed up to a maximum of 2.6 million tasks

Weak and strong scaling of SPARTA on Sequoia



Performance of SPARTA on Sequoia. Each line represents strong scaling. Cross-line performance represents weak scaling

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

RMI in Air-SF_6 Mixture: Mach 1.2 Shock

- A Mach 1.2 shock in Air (green) enters the computational domain from the top
- Following the refraction of the incident shock wave at the interface between two gases, a distorted shock is transmitted into SF_6 (red)
- As a result of this process, the interface is impulsively accelerated to a constant velocity
- Vorticity is generated baroclinically along the interface wherever the density (due to the initial interface) and pressure gradients (due to the shock) are misaligned
- This results in time-dependent growth of the initial perturbation
- The DSMC simulation employed a 10,000x40,000 cell domain, with x10 as many particles