SAND2015-2788D

SPARTA: A Scalable, Flexible Open-Source Direct Simulation Monte Carlo Code

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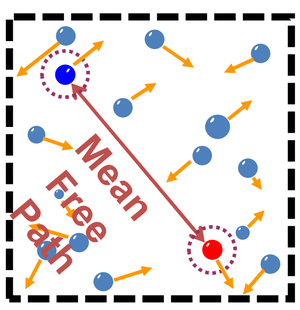
Problem

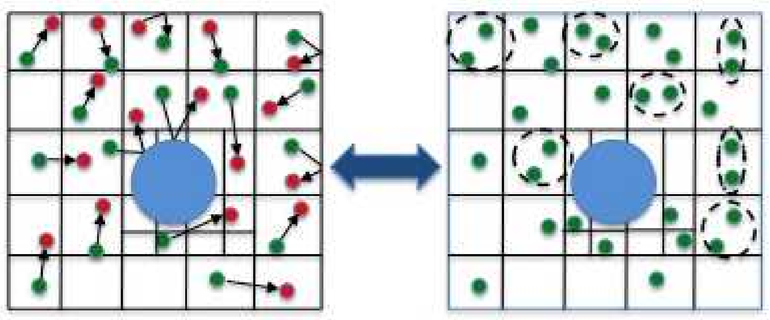
Simulation of re-entry vehicles

Critical for dynamic & thermal load calculation on re-entering spacecraft
Non-equilibrium, non-continuum conditions
Cannot be simulated with traditional CFD or reproduced experimentally

Approach



Direct Simulation Monte Carlo (DSMC)

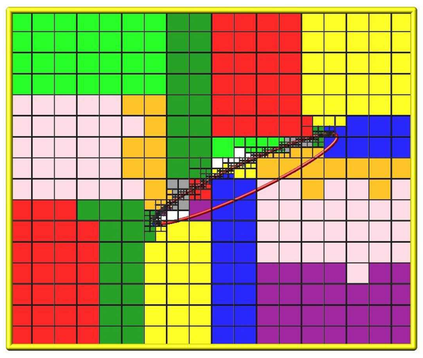


Move, Reflect **Collide**

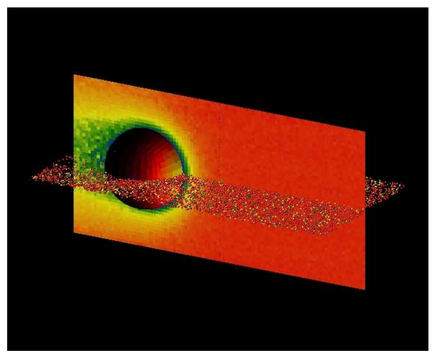
SPARTA = Stochastic PArallel Rarefied-gas Time-accurate Analyzer

- 3D, 2D, 2D axisymmetric, 1D
- Cartesian, hierarchical grid (up to 16 levels)
- Triangulated surfaces cut/split the grid cells
- Efficient communication, load balancing, *in-situ* visualization
- Extensible with new physics, diagnostics.
- Open source: http://sparta.sandia.gov

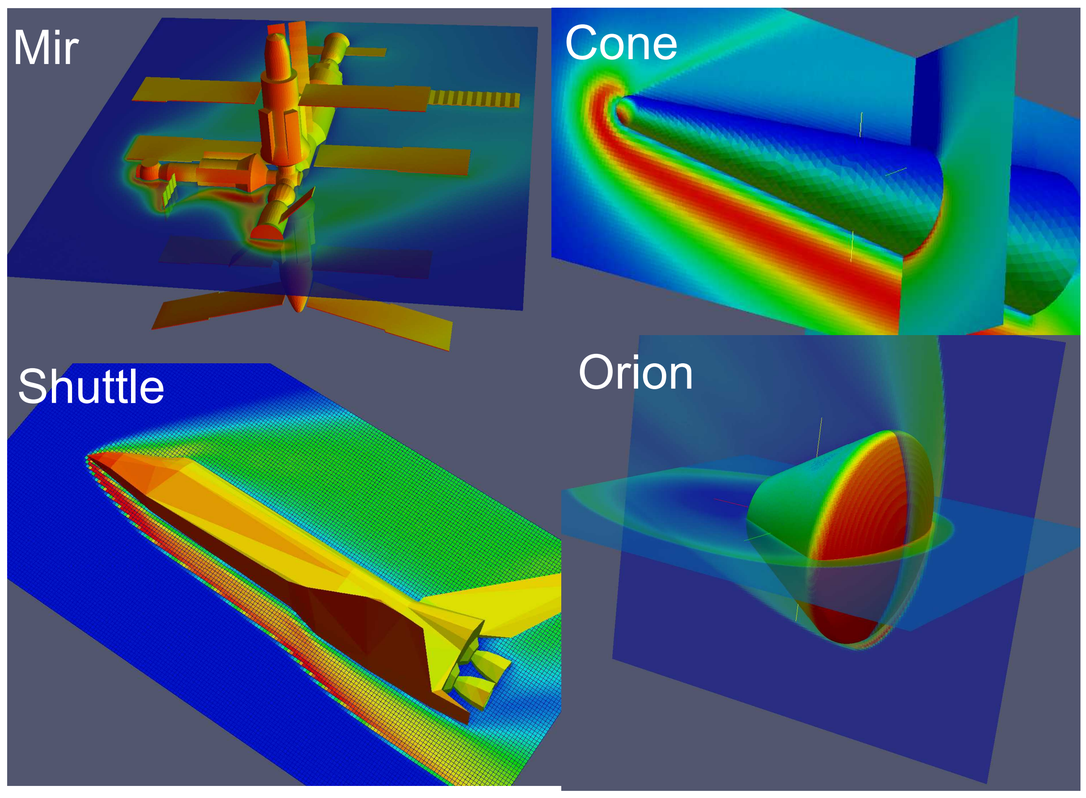
Hierarchical load-balanced grid



In-situ visualization



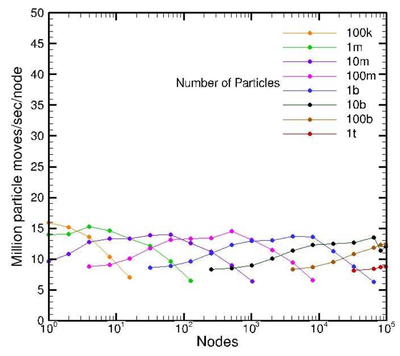
Results



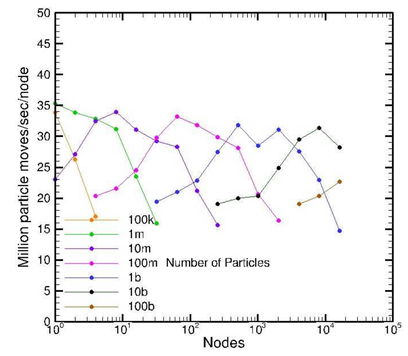
Largest simulation:
1 trillion grid cells, 3 trillion molecules

- 24-hr run on full LLNL Sequoia machine
- Scaling demonstrated to 1.6 million cores, 2.6 million MPI tasks

BG/Q Parallel Performance



16 cores/node
1 task/core



16 cores/node
4 tasks/core

Significance

Simulates hydrodynamic, non-equilibrium, chemically reacting, ionized flows.
Can model re-entry vehicles from free-molecular regime to below 200K ft.
Runs efficiently on variety of platforms: Mac/PC, Linux clusters, BG/Q.
500+ downloads since July 2014.

NNSA National Nuclear Security Administration
U.S. DEPARTMENT OF ENERGY

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SAND 2010-xxxP

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