Center for Compressible Multiphase Turbulence

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The overarching goals of the Center for Compressible Multiphase Turbulence (CCMT) are threefold:

- to radically advance the field of compressible multiphase turbulence (CMT) through rigorous first-principle multiscale modeling;
- to advance very large-scale predictive simulation science on present and near-future platforms;
- and to advance a co-design strategy that combines exascale emulation with a novel energy-constrained numerical approach.

The Center is performing petascale, and working towards exascale simulations of instabilities, turbulence and mixing in particle-laden flows under conditions of extreme pressure and temperature to investigate fundamental problems of interest to national technological leadership. Beginning in March 2014, CCMT began engaging approximately 25 graduate students and research staff in fundamental research in the areas of physics, uncertainty budget, computer science, and exascale modeling and simulation.

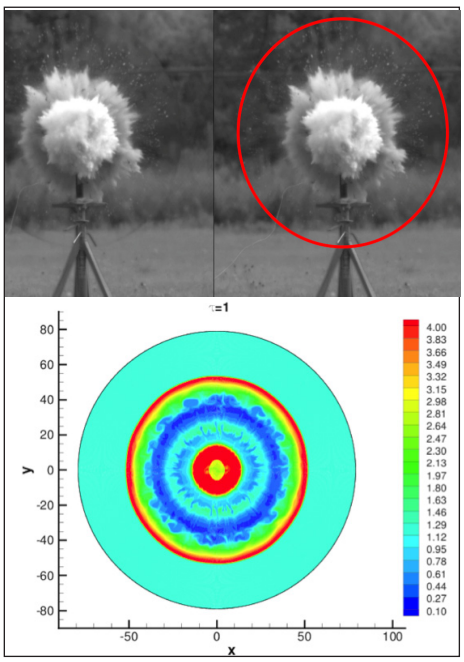

Figure 1. Experiment (top) and simulation (bottom) at early times of a cylindrical charge with inert particles.

Professor S. Balachandar notes that the Stewardship Science Academic Programs has brought international attention to the University of Florida, recognizes their commitment to high-speed computing on current and near-future platforms, and engages students from a wide spectrum of research interests to work together in tackling some of the world's most difficult problems. Most noteworthy, new classes and course materials are being developed in response to the program.

The chosen CMT demonstration problem for the initial phase of the research activities is an explosive dispersal of solid particles that consists of a detonator connected to a charge, which runs across the length of a cylinder filled with iron powder. The mid-section of the cylinder is occupied by a matrix enclosing a cloud of inert spherical glass particles. The computations aim at simulating the evolution of the mid-section of the cylinder. See Figure 1 for preliminary simulations. The state-of-the-art simulations of this problem at the micro-, meso-, and macroscales, along with companion validation-quality experiments will allow us to better understand the fundamental physics of compressible multiphase turbulence and translate this understanding to a rigorous multiscale modeling and simulation approach that can impact a wide variety of problems of national and societal importance. Uncertainty reduction is a key goal of the Center and it will drive micro- and mesoscale-informed model development, apart from error reduction in both experimental and numerical approaches. The uncertainty budget will drive the overall development of models, software, simulation, and calibration/validation experiments.

Shown in Figure 2 is a concept diagram of the exascale emulation project within CCMT. It is based on a coarse-grained simulation approach that is analogous to rapid virtual prototyping. Exascale emulation will provide an accurate first-order approximation for performing design-space exploration on extreme-scale, future-generation systems before (and complemented by) time-consuming detailed simulation/emulation. As shown in the figure, the project is divided into three major tasks. Task A is Behavioral Emulation Object (BEO) modeling, calibration, and validation of application kernels (App BEOs) and systems (architectural BEOs). A BEO is a model that is used as a surrogate of the real (existing) or notional (future) application or architecture. Task B is testbed experimentation and benchmarking used to calibrate and validate the developed models (BEOs). Task C is development of the behavioral emulation platforms. Currently, the exascale group is exploring the use and development of three platform types: discrete-event simulator, a symmetric multiprocessing simulator on many-core computer, and hardware emulator on a reconfigurable computer.

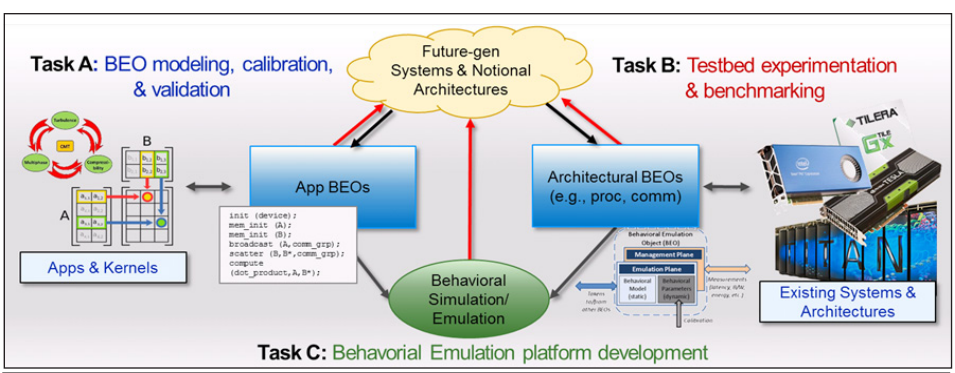

Figure 2. Concept diagram for Exascale emulation for future-generation systems. Task A is behavioral.

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