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SIERRA/Fuego/Syrinx Low Mach Fluids/Radiation Transport Code

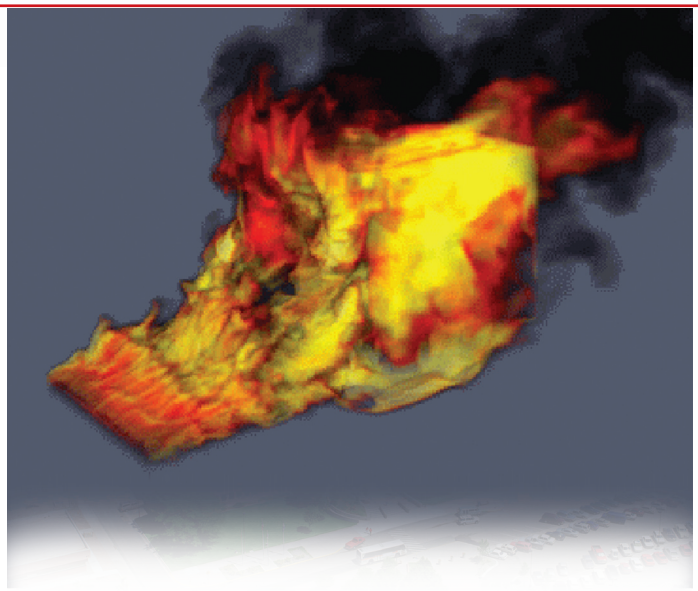
Thermal/Fluids Computational Engineering Sciences Department 1541 at Sandia National Laboratories provides high-fidelity, verified, software-quality assured, massively parallel multi-mechanics coupled analysis codes to the tri-lab community to solve complex problems. SIERRA/Fuego/Syrinx, with coupling to SIERRA/Calore, supports the capability to simulate the abnormal-thermal environment (i.e., transient object heat-up in hydrocarbon pool fire environments that might arise during transportation or storage-accident scenarios).

SIERRA/Fuego/Syrinx

has been developed under the object-oriented SIERRA Frameworks to easily facilitate multi-mechanics coupling to provide a robust simulation capability for highly sooting, buoyancy-driven turbulent-reacting flow mechanics. The core capability in SIERRA/Fuego is simulation of three-dimensional low-Mach-number turbulent-reacting flows on heterogeneous topological meshes (e.g., a mixture of hexahedral, tetrahedral, pyramid, and wedge elements). An approximate projection algorithm is used with Control Volume Finite Element Method (CVFEM) discretization. SIERRA/Syrinx solves the steady radiation transport equation using Streamwise Upwind Petrov-Galerkin discretization. The combined capability, in addition to coupling of the thermal-analysis code SIERRA/Calore, is required in the qualification effort for weapons in abnormal thermal environments.

Applications

SIERRA/Fuego/Syrinx is widely used to simulate applications as diverse as fire environments and laminar natural convection environments. The code primarily simulates buoyancy-driven turbulent-reacting flow in abnormal thermal environments (fluids, participating media radiation [PMR], and heat conduction). However, the core capability of this simulation tool is laminar/turbulent fluid mechanics and a combination of thermal/isothermal and uniform/nonuniform (with reactions) transport.



SIERRA/Fuego/Syrinx/Calore simulation of the proposed Thermal Test Complex Cross Wind Facility. The simulation includes one fluids and [S4] PMR region with two conduction regions (only outside container seen). 400 million dof; 5000 processor Red Storm run; shown is the volume-rendered temperature field.

Features

Unique features of SIERRA/Fuego/Syrinx that enable the code to solve complex problems include the following:

- Scalable, parallel solutions (optimal scaling demonstrated up to available resources, i.e., 40 million node mesh; 4096 processors).
- RANS turbulence models including the v^2-f model of Durbin, standard k-ε with wall functions, low Reynolds number models, and Large Eddy Simulation (LES) models including k-sgs, dynamic Smagorinsky and TFNS.
- Heterogeneous topology support (e.g., hexahedron, tetrahedral, pyramid, and wedge elements).
- Conjugate heat transfer coupling capability either with simple SIERRA/Fuego conduction region(s) or complex SIERRA/Calore conduction region(s).
- Seamless, state-of-the-art solver/preconditioners (e.g, multi-level methods, through input file declarations of solver libraries such as Trilinos, PetSci, Hypre, Prometheus, etc.).
- Advanced user subroutines

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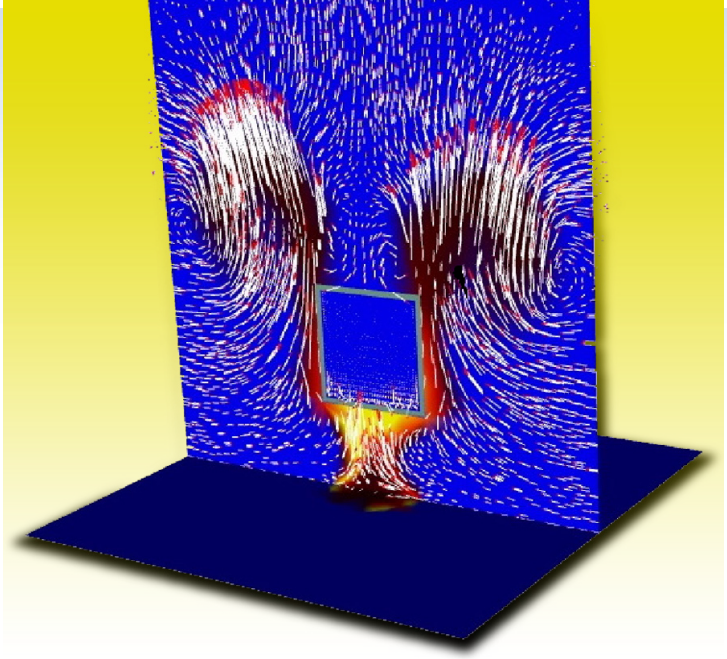

SIERRA/Fuego/Syrinx/Calore/Fuego complex coupled mechanics demonstration simulation. Outer unstructured hexahedral fluids/PMR region is represented by a fire mechanics while inner hexahedral region is a laminar natural convection mechanics. The tetrahedral conduction region (SIERRA/Calore) includes an inner chamber within which radiation occurs. Shown is gas-phase temperature with overset velocity vectors during plume start-up.

Verification

Because SIERRA/Fuego/Syrinx supports the Department of Energy's nuclear weapons mission, the team has identified and executed a detailed verification plan. Software Quality Engineering conducts mandated nightly regression tests on a variety of supported platforms. The team has also researched and developed the use of the method of manufactured solutions for the k-ε turbulent mechanics as part of the detailed verification test suite.

Validation

A substantial validation effort by the ASC V&V program has been performed for the mathematical models within SIERRA/Fuego/Syrinx. Each study leverages high-quality experimental data obtained expressly for validation purposes.

Future Capability

Future capability centers on implementation of Lagrangian Particle support (propellant fire and fire suppression system modeling), heterogeneous solids combustion, exploration of incorporation of Level-Set/Volume-of-Fluid methods, and SIERRA/Adagio coupling.

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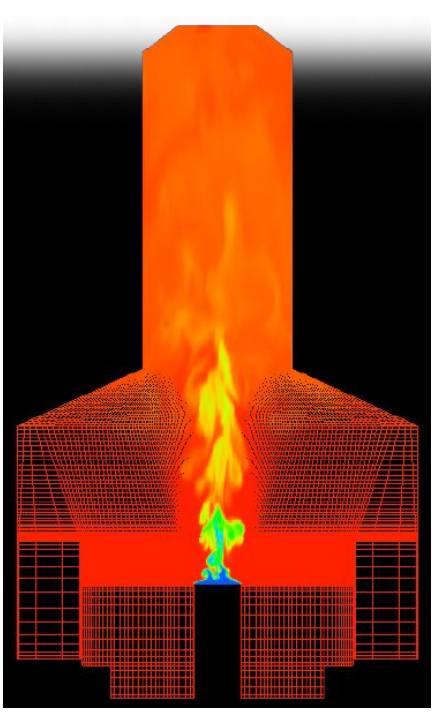
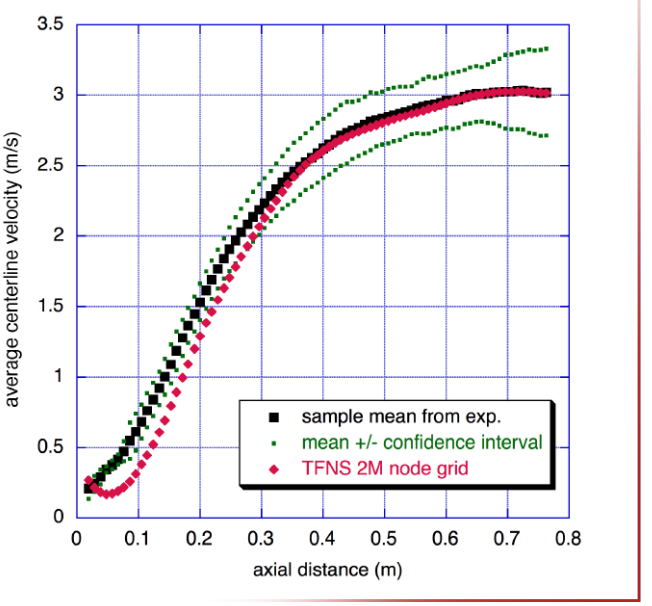


SIERRA/Fuego two million node mesh (in FLAME) Helium Plume ASC V&V study of the Temporally Filtered Navier Stokes (TFNS) turbulence model. Shown is a snapshot of instantaneous density (left) and comparison to centerline data obtained by PIV (right).



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