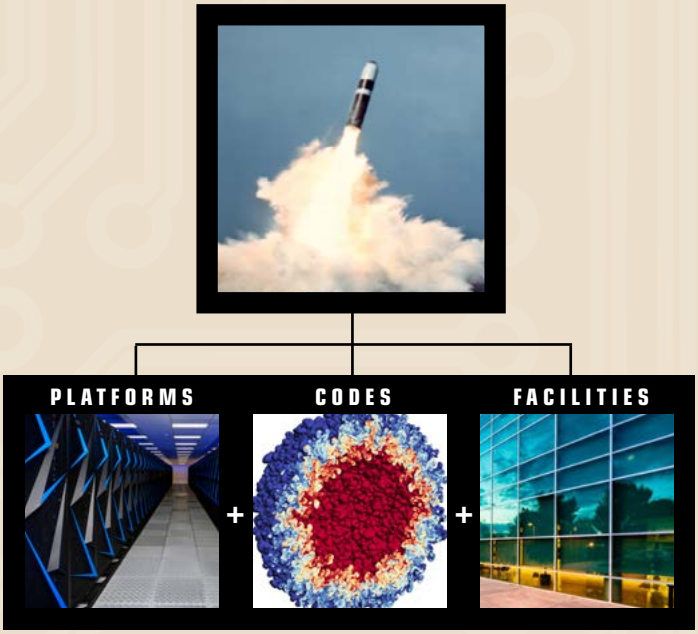
SIERRA

NNSA's largest and most advanced supercomputer will help solve the nation's most demanding computational challenges in support of nuclear security

MISSION BACKGROUND

Since the end of nuclear testing in 1992, the role of simulation and computing has steadily increased. As the stockpile ages and evolves away from what was tested underground, simulation and computing have, by necessity, been driven to be more predictive and less reliant on calibration to known results. A critical enabler in providing more predictive and higher fidelity computational models is the computational power needed to run those models. Sierra represents a dramatic increase in that capability. Sustainable support of the National Nuclear Security Administration (NNSA) mission requires that the Advanced Simulation and Computing (ASC) Program provide the computational tools to:

- **Address the unprecedented growth and diversity of security threats to the U.S. stockpile**
- **Enable the development of a more responsive and flexible stockpile capable of meeting evolving U.S. strategic interests**
- **Enable a more responsive infrastructure through agile and efficient manufacturing (e.g., pits)**
- **Support a broad range of national security interests**



In addition to enabling higher-fidelity, more-predictive simulation capabilities, Sierra will allow current state-of-the-art simulations to turn around much more quickly, providing the ability to run large ensembles of simulations to quantify the uncertainties in their predictions. Quantification of uncertainties not only allows decision makers to make more confident decisions, it also helps guide future research efforts, given that we know where our largest uncertainties lie. NNSA's approach to providing state-of-the-art simulation and computing capabilities uniquely embraces an integrated strategy that closely ties together the development of technologically advanced high-performance computing (HPC) platforms, next-generation codes, and modern facilities.

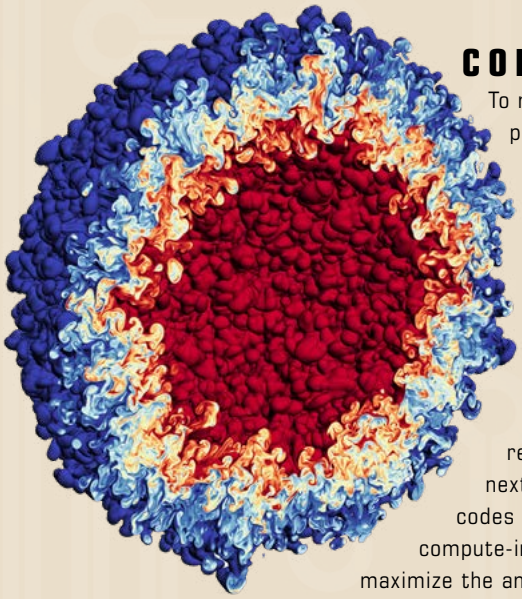
SIERRA STATISTICS

- **Peak performance: 125 petaflops (10^{15} floating-point operations per second)**
- **Memory: 1.38 petabytes**
- **Central Processing Units (CPUs): 8,640**
- **Graphics Processing Units (GPUs): 17,280**
- **Power consumption: 11 megawatts**
- **Network: Mellanox Enhanced Data Rate (EDR) Infiniband, 100 gigabits per second**

PLATFORM

Sierra is the latest in a series of leading-edge ASC Program supercomputers and was procured under the CORAL (Collaboration of Oak Ridge, Argonne, and Livermore national laboratories) partnership. The system will be shared by all three NNSA national laboratories: Los Alamos, Sandia, and Lawrence Livermore. Built by IBM in partnership with NVIDIA Corporation and Mellanox Technologies, Sierra is a heterogeneous supercomputer that uses IBM Power9 central processing units (CPUs) and NVIDIA Tesla V100 Tensor Core graphics processing units (GPUs). This heterogeneous architecture takes advantage of the enormous

parallelism in the GPUs to accelerate time-to-solution while providing greatly enhanced energy efficiency over previous systems. Sierra is the second-fastest computer in the world according to the November 2018 TOP500 list. It is the first production system of its kind produced for the NNSA and is currently one of the most promising architectures for future, exascale computing solutions.



CODES

To maximize the full potential of new computer architectures like Sierra's, new algorithms are being developed that play to the strengths of the machine—specifically, the high intensity of compute operations available for data that remain local. To this end, next-generation simulation codes employ high-order (i.e., compute-intensive) algorithms that maximize the amount of computing done for each piece of data retrieved from memory. The combination of next-generation, high-order algorithms with the processing power of Sierra will deliver an exciting new era in multiphysics simulations.

Until recently, computationally expensive 3D simulations were often run as a double-check on routinely employed 2D approximations. Three-dimensional simulations were employed only sparingly because their time to solution was too long to make them a practical, routine design tool. Sierra can process these crucial 3D simulations up to 10 times more rapidly, opening the door for weapons designers to employ 3D far more frequently. For example, simulations like the one depicted above, which shows hydrodynamic instability of two fluids mixing in a spherical geometry—relevant for inertial confinement fusion (ICF) and stockpile stewardship applications—are providing valuable data sets for understanding turbulence models. Using the full power of Sierra and involving an unprecedented 98 billion cells, the simulation was completed in less than three days, while it would have taken over a month on previous systems. Even so, such is the nature of 3D that the program awaits exascale computing to shift from routine 2D to routine 3D simulation.

NON-ASC APPLICATIONS

Lawrence Livermore is now heavily involved in a national effort to apply powerful computing resources that integrate simulation and artificial intelligence to solve major national challenges in areas including detection of nuclear nonproliferation, rapid development of cancer therapeutics, and addressing health care challenges facing veterans. In one such application, DOE will use machine learning and HPC to accelerate a precision approach to diagnosing and treating traumatic brain injury (TBI). Sierra's institutional unclassified companion system, Lassen, will enable LLNL scientists and partners from all over the country to produce faster and more accurate results for these applications based on much larger data sets and deeper science-based models.

FACILITIES

Simulation is the integrating element of the Stockpile Stewardship Program (SSP), and facilities are critical for simulation. Sierra is housed in LLNL's world-class computing facility in Building 453. The facility features a unique machine floor at 48,000 unobstructed square feet, 45 megawatts of machine power capacity, and 7,200 tons of computer cooling capacity. In anticipation of future exascale-class systems, the building is being upgraded by the ASC Program to 85 megawatts with commensurate cooling to be completed by late fiscal year 2021.

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