World's Fastest Computer

Hybrid supercomputer propels performance to 1,000 trillion calculations per second

Quick read
Los Alamos scientists doubled the processing speed of the former computing champ. Roadrunner, the new hybrid supercomputer, uses a video game chip to propel performance to more than a thousand trillion calculations per second.

Scientists want faster, more powerful high-performance supercomputers to simulate complex physical, biological, and socioeconomic systems with greater realism and predictive power. In May, Los Alamos scientists doubled the processing speed of the previously fastest computer.
Roadrunner, a new hybrid supercomputer, uses a video game chip to propel performance to petaflop/s speeds capable of more than a thousand trillion calculations per second.
"The computer is a speed demon. It will allow us to solve tremendous problems," said Thomas D'Agostino, head of the National Nuclear Security Administration, which oversees nuclear weapons research and maintains the warhead stockpile.
The computer might also have many medical and science applications, including developing biofuels or discovering drug therapies.
Modern supercomputers have thousands of identical computer nodes, each containing a microprocessor and a separate memory. The nodes are connected to form a cluster and work simultaneously on a single problem.

Left to right: Sriram Swaminarayan, Ben Bergen, John Turner, Mike Lang, Tim Kelley, and Jamaludin Mohd-Yusof represent the programming teams that proved Roadrunner could achieve its performance goals.

A huge obstacle to increased performance is the memory barrier. In the not-too-distant past, the time to fetch data from the node memory and load it into the processing units (called the "compute core") of a microprocessor was comparable to the time it would take that core to do the number crunching. Now the number crunching is 50 times faster than the time to fetch and load data. The time spent in data retrieval and communications can no longer be ignored.
Clearly, the old solution for increasing supercomputer performance—miniaturizing circuits and using faster clocks—is breaking down.
"We replace our high-performance supercomputers every four or five years," says Andy White, leader of supercomputer development at Los Alamos. "They become outdated in terms of speed, and the maintenance costs and failure rates get too high."
In 2002, when Los Alamos scientists were planning for their next-generation supercomputer, they looked at the commodity market for a way to make an end run around the speed and memory barriers looming in the future. What they found was a joint project by Sony Computer Entertainment, Toshiba, and IBM to develop a specialized microprocessor that could revolutionize computer games and consumer electronics, as well as scientific computing.

Roadrunner is a cluster of approximately 3,250 compute nodes interconnected by an off-the-shelf parallel-computing network. Each compute node consists of two AMD Opteron

dual-core microprocessors, with each of the Opteron cores internally attached to one of four enhanced Cell microprocessors. This enhanced Cell does double-precision arithmetic faster and can access more memory than can the original Cell in a PlayStation 3. The entire machine will have almost 13,000 Cells and half as many dual-core Opterons.

Named after the fleet-of-foot New Mexico state bird, the Roadrunner supercomputer is a hybrid, containing not one type of microprocessor but two.
Its main structure is a standard cluster of microprocessors (in this case AMD Opteron dual-core microprocessors). Nothing new here except that each chip has two compute cores instead of one. The hybrid element enters the picture when each Opteron core is internally attached to another type of chip, the enhanced Cell (the PowerXCell 8i), which has been designed specially for Roadrunner. The enhanced Cell can act like a turbocharger, potentially boosting the performance up to 25 times over that of an Opteron compute core alone.
Roadrunner Hits the Ground Running
If chosen to run on Roadrunner, supernova calculations using Milagro (Monte Carlo code) will be the first to determine the real influence of radiation flow on the light signals from these exploding stars.
Teams of physicists and computer scientists collaborated to restructure codes for a spectrum of important application areas, reimplementing sections as necessary for the new architecture.
The major application areas addressed were radiation transport (how radiation deposits energy in and moves through matter), neutron transport (how neutrons move through matter), molecular dynamics (how matter responds at the molecular level to shock waves and other extreme conditions), fluid turbulence, and the behavior of plasmas (ionized gases) in relation to fusion experiments at the National Ignition Facility at Lawrence Livermore National Laboratory. The corresponding codes represented a range of methods for solving equations on a computer.
Successfully accelerating Milagro took many months, several false starts, and modification of 10 percent to 30 percent of the code. The computationally-expensive Milagro was also executing six times faster with the Cell than without, a crucial achievement for the acceptance of Roadrunner.
Roadrunner is a tremendous asset to the Laboratory's nuclear weapons program simulations as well as for scientific grand challenges.
"We expect to see proposals in cosmology, antibiotic drug design, HIV vaccine development, astrophysics, ocean or climate modeling, turbulence, and we hope many others," researcher John Turner said.
By 2010 the Lab's scientists plan to use Roadrunner to help nuclear weapons performance. This is an important milestone in maintaining confidence in the nation's nuclear weapons stockpile without actual nuclear testing.

Supercomputing: Enabling Predictive Science

Read more:

- Senate resolution lauds Laboratory, IBM on Roadrunner
- Roadrunner supercomputer fastest in world
- Roadrunner computing time available

For more information about Roadrunner, see the Roadrunner Web site at http://www.lanl.gov/roadrunner
or contact LANL Project Manager Manuel Vigil, manuelv@lanl.gov, 505-667-4438.

About Our Capabilities, Facilities, and Staff

"Los Alamos National Laboratory plays an indispensable role in building America as a science and technology powerhouse, and our staff are an incredible resource to the nation and the world." Michael Anastasio, Dir.

Solving Complex R&D Problems with Special Blend of Staff, Capabilities and Facilities
Now in its seventh decade, LANL is one of the few laboratories that can bring great breadth of fundamental and discovery science, technology, and engineering rapidly together to

create tangible solutions for national security needs.
Our staff, working with partners throughout science and industry, must be able to deliver today's solutions while maintaining the depth of capabilities to deliver the next generation of discoveries.
Los Alamos has demonstrated a cycle of innovation where we have developed world-leading capabilities and facilities in response to urgent, unique missions. Our new discoveries continue to responde to emerging missions.
Being able to integrate and apply our capabilities rapidly to new challenges will be a key advantage in an increasingly competitive landscape.

Our Science, Technology and Engineering Priorities
Science that Matters

Information science and technology enabling integrative and predictive science
Experimental science focused on materials for the future
Fundamental forensic science for nuclear, biological, and chemical threats

How We Work

Collaborate, partner and team to make decisive contributions to our sponsors
Outstanding operational excellence for safety, security, and efficient pursuit of ST&E for our missions

Transform Our Scientific Campus

Campus for 2020 (consistent with complex transformation)
Modern science facilities: LANSCE refurbishment, CMR replacement, Science Complex
Signature facilities