Blue Waters: More Than A Name

Water gives life to Illinois' new supercomputer

Without water, life on Earth could not exist – and neither could the Blue Waters supercomputer.

When the National Center for Supercomputing Applications on the University of Illinois campus brings the new system online later this year, it will be the fastest computer in the world dedicated to open scientific inquiry from researchers worldwide. Blue Waters will top out at 10 quadrillion – or 10,000 trillion – calculations per second.

That mind-boggling speed could not be achieved without help from H_2O. And once the supercomputer is operational, one team of scientists will be using that power to help gain a deeper understanding of water on the molecular level.

If you've ever used a laptop computer on your lap, you know that computers produce heat. Most of them, from powerful supercomputers to simple netbooks, keep their processors from overheating by using fans to draw in cool air and expel hot air. That means there has to be enough open space inside for air circulation.

To conduct the complex operations for which they're used, supercomputers must quickly transfer information among multiple processors. Blue Waters will contain more than 37,000 IBM chips. Leaving enough room for air to move about would mean information would have to travel greater distances among processors, resulting in fewer possible calculations per second.

"In Blue Waters, and in most computers of the future, it's the latency [down time] of moving data that is really going to be … the thing that will limit its ability to do productive work," says **William Kramer**, NCSA's deputy project director for Blue Waters. "By shortening those distances, you shorten the latency."

That's where water comes in.

Instead of using air, Blue Waters will be cooled by water pumped through pinkie-sized pipes running across its circuit boards, thereby packing the supercomputer's components closer together and cutting down on the communication time among processors. Once operational, the system will require 8,400 gallons of recycling water per minute.

"It's not just the chip, but it's the actual packaging of the computer that will allow us to achieve our science goals," Kramer says. "The only way you can remove the heat is through liquid cooling. That's why the water is necessary; it's not just that it's nice to have."

In addition to helping boost the computer's processing power, the water cooling system will use approximately 40 percent less energy than if it were cooled by air, according to data from IBM.

Blue Waters' home will be the new National Petascale Computing Facility on Oak Street in Champaign, a block or so west of Assembly Hall. (While housed on the Illinois campus, Blue Waters is a joint venture of the U of I, NCSA, IBM and the Great Lakes Consortium for Petascale Computation.) When designing the building in 2007, NCSA hired mechanical engineer **Emad Jassim** '99 ENG, MS '01 ENG, PHD '06 ENG, to do preliminary design work on the facility's water-based cooling system.

The original idea was to use the University's nearby Oak Street Chiller Plant, which pumps cold water to air-condition buildings around campus. But, drawing on his years of experience in the heating, ventilation and air-conditioning industry, Jassim realized a more energy-efficient approach might work.

While the chiller plant pumps out water cooled to 43 degrees, Blue Waters will be able to operate safely at temperatures in the high 60s. Rather than relying on mechanically refrigerated water, Jassim suggested that the facility could use water cooled naturally by evaporation for much of the year. "This would save an enormous amount of money because then you don't have to operate as much energy-consuming equipment to cool it down as you would normally have to," he says.

That innovation helped NCSA attract more than $200 million in funding from the National Science Foundation to build the Blue Waters system, says **John Melchi** '91 MEDIA, senior associate director of NCSA. "That contribution was probably the single most important contribution in the entire construction process," he says.

When Jassim later became a lecturer and senior design project coordinator for the UI Department of Mechanical Science and Engineering, he supervised a team of seniors in spring 2008 who researched possible designs for the system. By using a year's worth of local hourly weather data to create their own solution, the students – **Stanley Berent** '08 ENG, **Ross Ratajczak** '08 ENG, **Andrew Thacker** '08 ENG and **Christopher Theis** '08 ENG – confirmed that the Chicago-based engineering firm hired to design the building would indeed be constructing the most efficient system.

The facility has three 10,000-gallon cooling towers located just outside of it. As water circulates through the Blue Waters system, heat is transferred from the computer's components to the water. This water is then pumped out to the cooling towers, where, when the out-

Photo courtesy of NCSA

In working furiously to conduct 10 quadrillion calculations per second, the Blue Waters supercomputer will be throwing off a lot of heat. To combat that problem, water — rather than air — will run through the system, absorb the heat and travel to outside cooling towers, above, which will rely on Mother Nature (most of the year) to lower the temperature inexpensively via evaporation. Pipes, shown below, will carry the cold water back to the supercomputer to start the cooling process again. Blue Waters joins the campus landscape that includes Memorial Stadium and Assembly Hall (in background above).

Photo courtesy of NCSA

side temperature and humidity are low enough, it is cooled by evaporation; the towers speed up this process by using fans to blow away the hot, humid air created by the evaporation process. They also provide water to air-condition the building.

NCSA estimates that Blue Waters will be able to use the evaporative cooling system more than eight months of the year; Kramer estimates a savings of up to $20 million in cooling costs over the supercomputer's five-year life span.

Water enables the existence of the Blue Waters supercomputer. In turn, the Blue Waters supercomputer will enable an Iowa State University research team to create the most accurate model to date of how water behaves on the molecular level.

"Water is so important to our daily lives, and it seems simple, but in actuality … it's a very difficult substance to understand from a fundamental standpoint," says Monica Lamm, a professor of chemical and biological engineering at Iowa State.

The group, funded by an NSF grant, is working with NCSA to prepare its computer code to run on Blue Waters. Once their models are running, other researchers will be able to use their data to study other water-related issues.

"Because of the nature of the problem, it's really going to open up more questions," Lamm says. "Because nobody has been able to do these types of calculations before, nobody knows what we will find, so that's very exciting."

– Dan Petrella

__Petrella__ '06 MEDIA, '06 LAS, MS '10 MEDIA, is a freelance journalist in Champaign.