Resurrecting the CDC 6500 Supercomputer

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Engineers at Living Computers: Museum + Labs have salvaged one of the world's first supercomputers.

Living Computers: Museum + Labs (LCM+L) in Seattle, Washington, is filled with historically significant computing technology that remains powered up so visitors can experience firsthand what computers looked and felt like decades ago. The museum, founded in 2005 by Paul G. Allen, has the largest collection of working restored computing machines. Walking past the many micro- and minicomputers into the back room with the raised floor, you can see one of the world's first-generation supercomputers: the CDC 6500, which fills several refrigerator-sized cabinets with electronics, wiring, and liquid cooling. Manufactured by the Control Data Corporation and designed by supercomputer pioneer Seymour Cray, the CDC 6500 was first announced in 1964 and customers took delivery of it in 1967.

Building the CDC 6500 pushed the available technologies to their limits. It was expensive to purchase and maintain, and had tens of thousands of custom parts and circuits. There were very few CDC 6500s built, and each system cost millions of dollars. Those that were built were only available to the government, research labs, and well-funded universities. At the time, the CDC 6500 was so powerful that it was considered a national asset and was thus illegal to export for quite some time.

In 2013, LCM+L acquired a CDC 6500 that was built in 1967 and ran at Purdue University until it was decommissioned in 1989. Some electronic parts were pulled out and melted for their gold content, and the chassis were disassembled using large wire cutters, pipe cutters, and crowbars to get the unit out of the machine room. It seemed impossible to resurrect, but LCM+L pulled it off. During my visit there, I spoke with principal engineer Bruce Sherry about what it took to bring this machine from salvage to production. View a video of our talk at www.computer.org/computingconversations.

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BRINGING THE CDC 6500 BACK

When LCM+L acquired the CDC 6500, they began the process of restoring it so that it could once again run in production. All of the connecting cables between the cabinets were cut when the machine was disassembled:

> *This machine was 22 years old when it came out of service. The first thing we had to do was get new cables. The cables were manufactured by three different companies, and none of the companies that were still in business would make us a cable. So we had to build them ourselves. One of the things we needed was the taper pins that go on the ends of each wire.*

The pins were manufactured by AMP, which was still in business. They had taper pins in gold or tin, but not in the silver that was required for the CDC 6500. With a bit of convincing, negotiating, and LCM+L's promise to purchase 50,000 pins, AMP agreed to produce a limited run of silver pins:

> *I have 40,000 pins sitting upstairs because I only needed 10,000 to put the machine together. That cost $40,000 and then we spent another $40,000 to build cables with the pins on the ends. It took about five weeks for my technician, Dave Cameron, to replace all the cut ends with the new cables.*

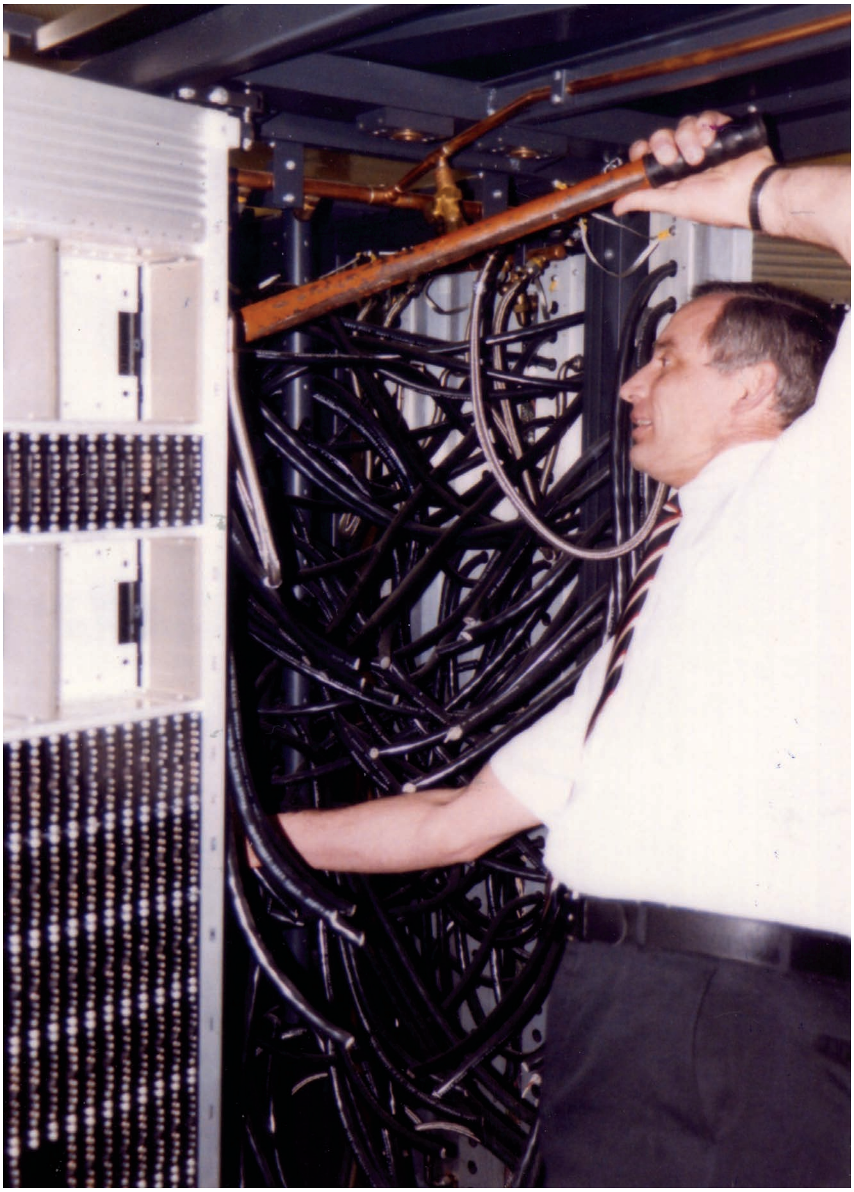

Figure 1. Joachim Nunnink cutting the CDC 6500's cables at Purdue University in 1989. (Source: Richard Waltz, used with permission.)

Once the chassis were reconnected, the next challenge was to bring the cooling system back up:

> *This is the first machine that was cooled with Freon. If you're near the computer, you can hear a little thumping in the background among all the noise the rest of the computer is making. That noise is from the compressors for the refrigeration system that cools the machine. Each one of the three bays has its own refrigeration system.*

The chilled Freon is pumped through small copper tubes so that every one of the logic modules is separately cooled:

> *We compress the Freon gas into a liquid that goes through a heat exchanger to transfer the heat into chilled water. The warm water is pumped up to a water chiller on the roof, which cost another $185,000 to install. The chilled Freon is pumped through hoses going into each of the 12 chassis.*

The chassis contain electronic logic modules with transistors, resistors, and capacitors to implement the CPU and peripheral processing units. Memory storage is provided using 170 core memory modules, each of which is about a six-inch cube:

> *Each one of these little blocks is 4K words by 12 bits, and for the main CPU there are five blocks to make a 60-bit word of the computer. So this chassis holds 16K words and we've got eight of those for a total of 128K words. I only have half of it working, so there are 64K words, or about half a megabyte.*

It's challenging to keep the memory modules running. They consist of a woven mat of core memory with fine wires running through the cores to read and write the data bit that was stored in each core. It's difficult to repair the core memory because everything is so small:

> *Each thing that looks like it might be a core is actually four cores on edge. Each core has five wires going through it and they're all suspended by the mat of wires that go through the cores.*

Because the logic modules are made up of separate transistors, resistors, and capacitors, it's sometimes possible to repair a failing module:

> *Your phone has about a billion transistors in it. The entire CDC 6500 has about 250,000 transistors, and each logic module has about 50 transistors. If the failing transistor is near the edge of the module, I can repair it because I can still get a slightly taller version of the transistor off the shelf at Digi-Key.*

When it's impossible to find a replacement for a component, LCM+L switches into "laboratory mode" to design and build a new component from scratch. The new component must meet all the physical size, power, and logic requirements of the existing module but can use modern parts. Bruce and his team were recently able to reverse-engineer and construct a replacement for one of the CDC 6500's logic modules using modern technology:

> *Final assembly was quite challenging because you have to put all of the resistors and diodes in one side and then try to slide them across and into the right hole on the other side. It's a rather tedious process, but it works.*

Once the CPU and memory were working, it was time to try to load software onto the computer and test whether it worked. They didn't have enough hardware to load an operating system onto the CDC 6500:

> *When we got this machine, we had three peripherals. We had a card punch, a printer, and a tape drive but no controllers.*

Without the controllers, there was no way to plug the hardware into the CDC 6500. So Bruce and his team used a Windows PC with a set of six field-programmable gate array (FPGA) cards to emulate the CDC controller and peripheral hardware:

> *Each of these FPGA cards is talking to one channel from the CPU. The first thing I had to do was emulate the dead start panel. Given that I was emulating it, I gave the panel 4K of instructions instead of the original 12. That allowed me to do a lot of diagnostics. The next thing we had to emulate was the display, because our real display didn't work yet. It's very fragile; we left it on over the weekend and a transformer blew up. It took four months and $15,000 to get a new transformer built. After we emulated the display, we had to emulate a tape drive and then the card reader, card punch, line printer, and disk drives.*

The emulated console looks very much like the original CDC 6500 with its soft green vector graphics and characters that flickered as the CPU communicated with the peripheral processors. Bruce compiled and ran the Linpack benchmark to give the computer something to do. It took six seconds for the CDC 6500 to compile the code stored on emulated disk drives and then executed for 45 seconds on the real CDC 6500 CPU.

It was a privilege to talk with Bruce and explore the history of the CDC 6500 and its restoration. I used punched cards to run FORTRAN programs on a CDC 6500 at Michigan State University in the late 1970s. By the mid-1980s, I was a professional developer supporting faculty use of the CDC 6500. I spent plenty of hours sitting at that green, glowing CDC 6500 console as an operator mounting tapes or debugging system issues. For me, spending time with Bruce and the CDC 6500 was like a 40-year class reunion. ◼

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