SEYMOUR CRAY and NSA October 5

Seymour Cray is widely viewed as the greatest architect and engineer of our time in the supercomputing field. He was withdrawn and reclusive, shy to a fault, notably to his own management and with rare exceptions, to the organizations that used his systems. Direct interaction by visiting NSA people seldom occurred, was very difficult to arrange, and for most of us, perfectly tolerable. Nonetheless, he clearly understood and highly valued NSA as a user and unquestionably knew the criticality of his work to our cryptologic mission.

Seymour Cray went from Minnesota University directly to Engineering Research Associates following his graduation with a BSEE and a Masters in Applied Mathematics in 1951. ERA was all but a captive Navy firm supporting, inter alia, Navy Cryptology with low volume, often one-off, systems, e.g., ATLAS.

This was an era of punched cards, paper tapes and tabulating equipment. The first digital computer employing vacuum tubes had been built just a few years earlier at Manchester University, based on Alan Turing's Universal Computing Machine.

Seymour was an immediate success at ERA: the magnetic drum was an early invention. His work was a major influence on the group that left the company to form Control Data Corporation (CDC), but it was not until 1957 that the Navy finally agreed to let Seymour move to Control Data. At Control Data, Seymour wanted to build supercomputers, but technology and funding were still limited. He turned from vacuum tubes to first generation transistors (invented only a year before), and the CDC 1604 became a reality. This was the first use of germanium transistors, a RISC architecture, and an elegant interconnection system. The 1604 went onto the market in 1960 and became an instant success. This success elevated CDC to industry leadership in High Performance Computing (HPC).

Cray was an important factor in developing a system NSA called BOGART. This was a small 16k machine with a magnetic drum and ideal for hands-on data manipulation. It was the first system that allowed access by remote terminals.

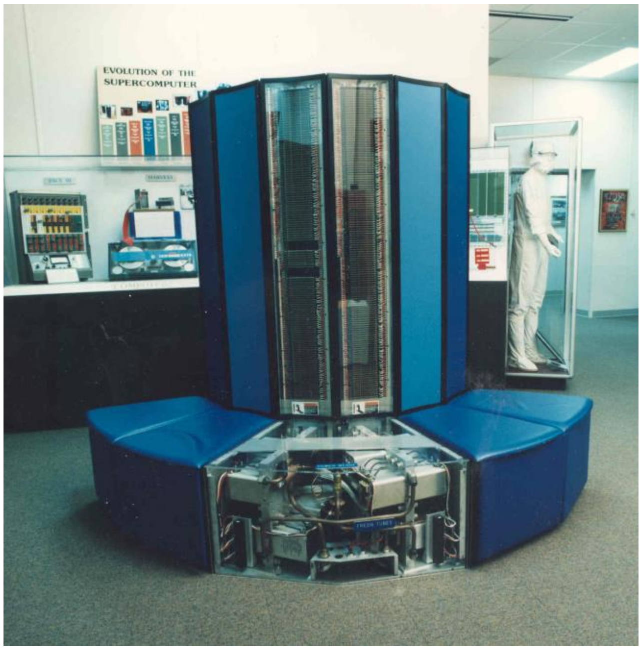
Seymour wanted the fastest possible high-end computer with a small instruction set, and began work on the CDC 6600. A new silicon-based transistor caught his attention; it was considerably faster than the germanium transistors used in the 1604 and it was the breakthrough that he needed. However, Cray was obsessed with the need for quiet and seclusion and convinced CDC to move his laboratory and the 6600 efforts to Chippewa Falls, Seymour's home town in 1962.

By mid-1963 the CDC 6600 machine, 50x the 1604 with Freon cooling, innovative packaging and the new transistors, was finished. At $8M a pop, over 100 were sold. The Agency bought two 6600s and a 6400 for use in ELINT processing, a numbing workload that was both a political nightmare and critical to the Viet Nam war that was rapidly heating up.

Seymour never thought of the use of his scientific supercomputers for "Big Data" processing but the inherent parallelism of the machine made it a good choice at NSA. He was seriously troubled by the prospect of nuclear war, and knew his machines were critical to the Cold War efforts. (Seymour actually built a major fallout shelter in the hillside behind his home.)

Work on the follow-on 7600 began immediately; as usual Seymour left it to his staff to clean up the aftermath of the 6600, get it into production, and fend off the press and salesmen who tried to get access to him. The 7600 was four times faster than the 6600. It became an NSA "workhorse," and put the Agency into the big league of production High End Computing on mission-critical work.

Development of the next in the series, the CDC 8600, went very slowly. The major issue was Seymour's goal of an 8 ns clock cycle, which he would achieve by using four processors in parallel. But the engineering team could not get generated heat under control with the compact integration Seymour wanted. Seymour's computers were still assembled at the board level with transistors, resistors, and capacitors soldered on a circuit board, with wires kept as short as possible. It illustrated another characteristic of Cray; although a great innovator, he would also often stick with technologies he had depended on earlier. He gave up his salary to stay in budget but could not get the 8600 development finished.



The Cray 1 on display in the National Cryptologic Museum. Notice the "seats," which circulated the coolant.

In 1972, he left CDC with six other engineers and a $250,000 CDC grant to found Cray Research Inc., with the goal of building the world's fastest computer. By September 1972 he was in a new, much smaller lab near his home and began development of what would be known as the Cray-1. This machine would use integrated circuits (ICs) with all components within a single piece of silicon. Boards were smaller but much denser, with more circuits, and cooling with Freon (incorporated in the "seats.")

Cray Research was operating on a shoestring budget. Seymour recruited John Rollwagon, an MIT EE and Harvard MBA as CFO. When Seymour agreed to take the company public, venture capital assured he could finish the Cray-1. The task of selling the machine fell to Rollwagon. Serial 1 was shipped to Los Alamos National Lab and demand exploded with 8 per year scheduled.

In 1978, with the Agency's planned acquisition of its first Cray-1, Seymour agreed to visit Fort Meade and give a talk about the machine to Agency cryptanalysts and programmers. The machine was an instant hit, even though its operating system and Fortran compiler were more compatible with National Lab uses than NSA's. An OS peculiar to NSA, *Folklore*, had been developed for Cray machines. A "Folklored" Cray-1 with a dedicated tube-room for cryptanalysts became the first "client-server" system in NSA and changed the relationship between HPC and the cryptanalytic community forever.

Seymour began thinking about a follow-on to the Cray-1 even before it was in the market. He departed greatly from the Cray-1 architecture for the Cray-2. It was to be a four-processor scalar machine with an astonishing 64 scalar processors, a massively parallel machine, although the idea of 64 scalar processors eventually was dropped. This whole concept was a radical departure for Seymour, who had stubbornly clung to classical technologies while focusing on near-genius ways of integrating them into a new architecture. His overall architecture involved an 8-layer set of boards, with metal layers between and connecting wires through the entire set. This presented a massive cooling problem, solved by immersing the entire system in a tank of florinert, which was pumped at a high rate through the electronics.

However, none of this happened overnight. Delays due to budget and management led to issues significant delays in completion of the Cray-2.

It's important to understand how the Agency responded to these developments in its own HPC planning. The esteem held for Seymour never wavered but tracking on development of the Cray-2 was hard. The Cray-1, as with all supercomputers of the day, had a finite lifetime, 3 -4 years. Programming and budgeting for HPC was an art, not appreciated by the folks in green eye shades. The scalar nature of the Cray-2 was not appealing to some NSA technical staff. Porting the Folklore OS to a new architecture was a “black hole” of uncertainty. Nonetheless, the Agency trusted Seymour. He had delivered before and would again. But Seymour and CRI bogged down badly in the Cray-2 development.

The Cray 2 was finished in 1985; NSA acquired one shortly after, attracted by its massive memory. It proved to be a difficult machine to program.

It’s also important to try to understand the nature of the man responsible for all this. He was reclusive, yes. He was introverted, yes. And he was indifferent to management and financial demands. He did not suffer fools at all. With those flaws, he had tremendous capabilities in understanding the potential for binary, digital computing. He was not a circuit designer but what he didn’t understand, he spent days in personal reflection on, in absolute seclusion. He had near total dependency on key engineers and associates, Les Davis, John Rollwagon, Dean

Rousch, an expert in refrigeration, and software experts. Seymour Cray was an excellent judge of technically-good people. The world outside his world did not understand much of this. But it was at the core of his success as the greatest high-end computing architect of the last five or six decades.

CRI moved into design of a parallel processing system called the XMP, while Seymour continued with the Cray-2 development. He had many frustrations with the development: although he had solved the cooling issue, fabrication of the boards had all but shut down the project. He left it to others, in 1984, to finish the Cray-2, turning his total attention to his follow-on machine, the Cray-3. Here, Seymour took a hard turn, staring processing speed in the face and not (yet) being prepared to adopt massive parallelism. He knew he could not fight the laws of physics on the speed of light through copper; he knew he had reached the end of the line on system integration, so he turned again to architecture and was convinced that Gallium Arsenide (GaaS) was six times faster than silicon. He convinced CRI to invest $20M in a GaaS lab in Chippewa Falls.

The Cray-3 suffered many of the same illnesses that affected the Cray-2. Chip design, for example, was delayed months waiting for delivery from the fabrication facility. At every turn, new assembly or test equipment had to be developed to get to the next phase. In early 1989, CRI, struggling with financial issues and after negotiation, agreed with Seymour’s proposal to break off the Cray-3 into an independent company headed by Seymour, titled Cray Computer Corporation. However, delays continued and its first customer, Lawrence Livermore, cancelled its contract for a Cray-3, due in mid-1992, after several missed milestones.

Unlike the Cray-3, Cray-4 development went very smoothly. However, in March 1995, Cray Computer Corporation was out of funds and filed for bankruptcy. A desperate effort to raise funding from federal customers, including NSA, failed.

Seymour Cray, meanwhile, would not give up. Accepting the transition of HPC to commodity technologies, he set off once again to develop a massively parallel, but industry leading, system. This all ended suddenly when Seymour was critically injured in an automobile accident and died two weeks later, October 5, 1996.

What is truly amazing when reflecting on Seymour's life is that his introduction to computing occurred in the era of electromechanical technologies and vacuum tubes, morphing from just two cryptologic communities, one UK (Alan Turing and Bletchley Park) and the other CSAW, predecessor to today's Tenth Fleet. Seymour's life ended with an unparalleled string of successes, the leading supercomputers of the Information Age. He had no equal in his ability to literally "see" the architectural and technology breakthroughs essential to get to the next level of performance. And what is also truly amazing is the extent to which his unique developments have endured in the industry to this day.

It is not without reason that the highest award in this community is the IEEE/ACM Seymour Cray Award, given annually. The awardees are the "Who's Who" of High End Computing.

When the full history of the Cold War is finally written, it must credit the U.S. Intelligence Community with much of the victory. Time and time again, the USSR found itself on the losing side of weapon matchups, second to U.S. defense industry's best, its kinetic warfare options limited to nuclear weapons, and now its rusting fleet and immobile armies forcing Russia into asymmetrical I/O games. NSA contributions were abundant. Seymour Cray can rest easy, his machines played an enormous part in NSA's role in winning the Cold War. And his magnificent output continues on in the systems being developed today.

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