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'The Mind's Eye' and the Computers of Seymour Cray

A few years ago I spent a summer at the Computer Museum, which at the time was in the process of opening its public space on Museum Wharf in Boston. One day the Director, Dr. Gwen Bell, asked me to go to a back room, remove a circuit board from a computer there, and bring it out in preparation for display. I was accompanied by a summer intern, who by that time had already gained a lot of hands-on knowledge of the museum and its (at the time) unusual collections. The computer was a 'Naval Tactical Data System' (NTDS), built by Sperry UNIVAC for the U.S. Navy. When we opened it up, the intern looked at me and said, 'It's pretty obvious that Seymour Cray designed this machine, isn't it.'

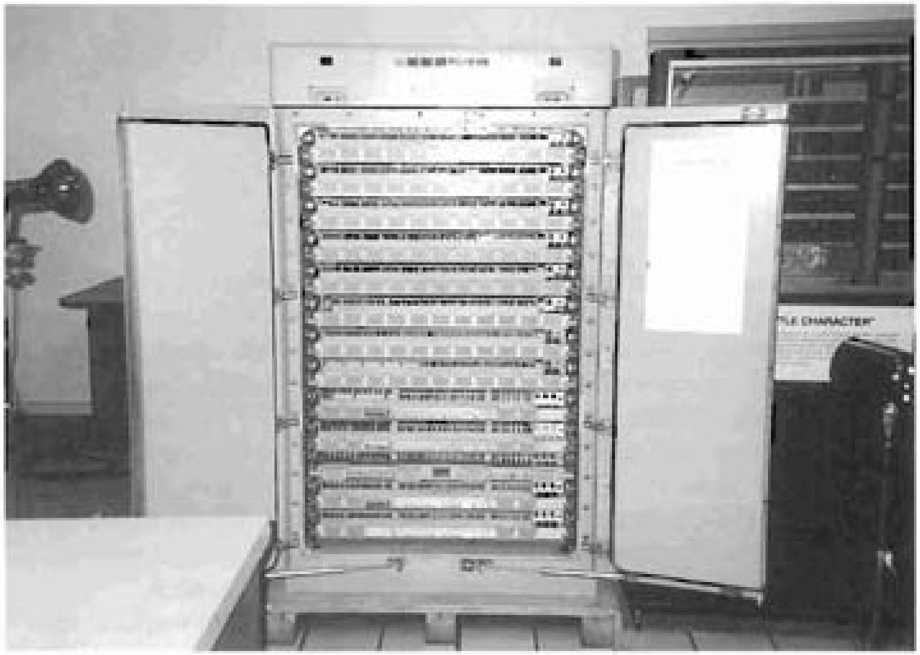
He was correct. Seymour Cray was involved in the initial work on the NTDS. The Naval Tactical Data System was a specialized computer built for the U.S. Navy. It was not well-known outside the small and highly-specialized military market. It was built by Sperry UNIVAC, a company that few people even today know that Seymour Cray ever worked for. Cray left Sperry UNIVAC by the time the final product was designed and built, and there was little in the published record that documented his involvement with this machine. His name appeared nowhere on the machine, nor in any technical manuals or other descriptions that we had of it at the time. So what did the intern know, and how did he know it?

This paper is an attempt to answer those questions.

Most curators involved with museums of technology are familiar with the notion of visual, as opposed to verbal, 'readings' of technology, as developed by Eugene Ferguson in his influential article on 'The Mind's Eye,' first published in 1977 and later expanded into a book.[1] Curators who collect and exhibit artifacts related to microelectronics and computing find that, perhaps, those ideas may not be as helpful as they are when dealing with earlier technologies, whose mechanisms are more easily seen and grasped by the observer. One obvious clue to this problem is the term often used when discussing electronics: black box. The implication seems to be that at some point one turns away from an attempt to understand what is going on inside.[2]

This is of course a much-condensed statement of the issue of black boxes, and I hope I have not done too much harm by summarizing it so briefly. I do believe it is not a distortion of the reality faced by many curators in museums of moden technology, who face the task of developing exhibitions on computing and electronics for a mass audience.

Figure 1. UNIVAC NTDS Computer, ca. 1962. The NTDS was built for installation on board navy ships, and so was housed in a rugged, water-tight box. UNIVAC also marketed a commercial version, which was electrically identical but packaged in a more conventional housing.



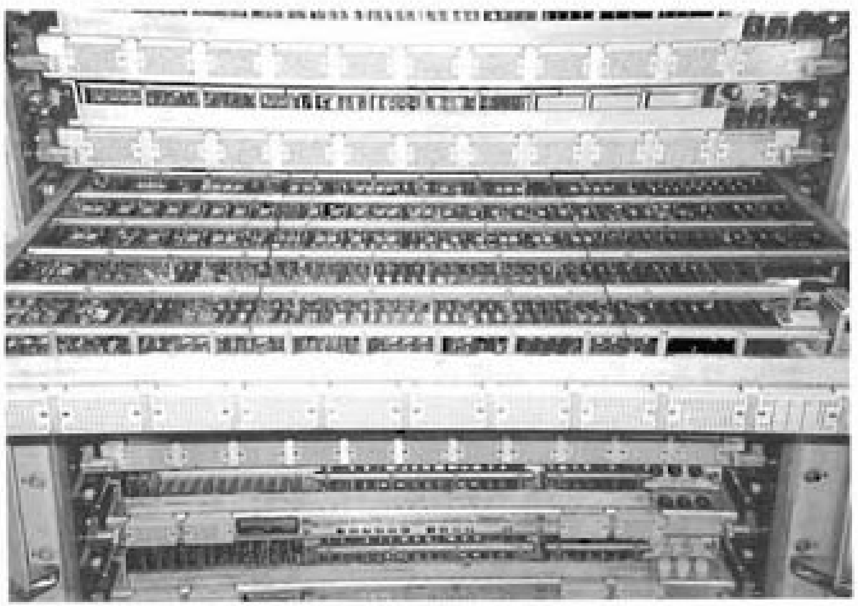


Figure 2. Close-up of the NTDS Circuits. The dense packing of the individual circuits was an indication that Seymour Cray was involved. The NTDS used discrete transistors, not integrated circuits.

Figs. 1 and 2 Courtesy of the Computer History Museum.

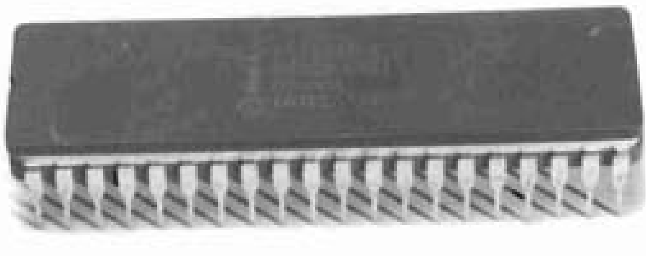


Figure 3. Intel 8080a chip, ca. 1975. The 8080 was used in the early personal computers and led to the 8086x series that still dominates personal computing. Like most integrated circuits, the chip itself is encapsulated in a black, rectangular housing, with electrical contacts protruding from two sides in parallel rows. This so-called 'Dual In-line Package' (DIP), invented around 1970, remains in common use in the electronics industry, in spite of enormous advances in chip density. (Photo: Smithsonian Institution, 92-7008-29)

Although I feel as passionately about these artifacts as those who study older, classical machines, I seldom experience the kind of pleasure Ferguson describes when analyzing the design, say, of a motorcycle engine. For the past 25 years—an eternity in computing history—digital computers have been made of small, black, rectangular chips, soldered onto rectangular printed circuit boards, which in turn are plugged into a bus, or backplane, that supplies power, communication signals, and so forth. The whole arrangement is housed in one or more rectangular boxes. Not much to read, it seems.

The intern's reading of the NTDS computer suggests an exception to this state of affairs.

Seymour Cray (1925–1996) was a legend in the computer industry for his design of supercomputers—machines that could calculate much faster than any others. Supercomputers were eagerly sought by government and defense agencies such as the U.S. National Security Agency, the Lawrence Livermore Labs, and NASA. Their export to other countries, even those friendly to the U.S., was restricted, although that policy was probably as much a matter of politics as it was a matter of technology. For this discussion, more relevant than the politics of its use or the work it did was that Cray computers designed after 1976 were circular or semicircular in shape—a rare exception to the rectangular boxes that characterize all other computers, large and small.[3]

As Donald MacKenzie and Boelie Elzen have pointed out, the success of the CRAY-1 was due to a complex mix of factors, technical, social, and political.[4] I have already mentioned the political factors that restricted the export of these machines; to that MacKenzie and Elzen add the cult of personality that surrounded Seymour, a result of his Midwest roots and demeanor, his distaste for bureaucracy, his refusal to talk to the trade or

Figure 4. Seymour Cray, standing next to a CRAY-1 computer, ca. 1976. The naugahyde-covered power supplies are visible in the lower part of the photo. Each segment of the CRAY-1's processor had its own dedicated power supply. (Photo: Cray Research, Inc. SI photo # 89–21494).

Figure 5. A typical installation, with the processor surrounded by a 'farm' of disk drives that make the room look a bit like a laundromat. (Photo: Cray Research, Inc.).

popular press, and finally, the unique shape of his designs. (Part of the cult is that people usually refer to him by his first name.)

In one of his rare public appearances, Cray described how he arrived at that shape as a result of a desire to minimize the time a signal would spend traveling from one end of the computer to another. The interior, containing connecting wiring, had however to be large enough for a small-framed person (typically a woman) to squeeze inside and make a repair if necessary. Power supplies had to be located close to each set of circuits, to minimize power losses. Thus he arrived, for what he described

Figure 6. Wiring a CRAY backplane. Cray computers were laboriously handwired, to give the fastest possible speeds for signals to travel from one part of the computer to another. A) Seymour Cray had a plant built near his home in the remote town of Chippewa Falls, Wisconsin to do this final assembly. He stated that it was easy to find, hire, and train a highly-capable workforce, mainly women, from the surrounding region to do the work (Credit: Cray Research, Inc. SI photo # 89–21495).

as purely rational reasons, at the three-quarters circular column, with a lower bench containing the power supplies. The padding on the bench was perhaps his only concession to whimsy. Although the machine has been called the 'world's most expensive love-seat,' the owners of a multi-million dollar machine would seldom allow people to sit there unless they had a good reason do so.

A closer look at the design suggests that perhaps it was not so rational after all. The circle was not closed; thus the time it would take for a signal to travel from one end to the other was only slightly less than it would have been had the circuits been laid out on a rectangular frame. Except for the CRAY-2, other machines produced by Cray Research, including the CRAY X-MP, Y-MP, and all subsequent computers, either were rectangular or had only a vestigial reminder of the semicircular shape. That may have been for marketing as well as for technical purposes. The computers that Seymour designed before founding Cray Research, including the NTDS mentioned above as well as the Control Data Corporation CDC-6600 (his first supercomputer) were all rectangular.

What really distinguished all of Cray's designs, and what enabled the intern to recognize his early work so readily, was that Cray succeeded in packing circuits to a density that no one else could approach. For his pioneering CDC-6600, Cray packed the resistors, transistors, diodes, and other components so densely they resembled stacks of firewood; the process was called cordwood packaging. To do that he had to face and solve a daunting problem. Electronic components give off heat, but in a dense package there is little room for the heat to escape. Cray came up with innovative liquid cooling techniques that, in may respects, were the key to his success with the CDC-6600 and the CRAY-1. Among computer engineers, Seymour is remembered as much for the genius of his packaging and cooling techniques as he is for his brilliant mastery of electronic circuit design. The CRAY-2 was completely immersed in a bath of liquid to keep it from overheating.

A person with some familiarity with packaging can thus recognize a Seymour Cray machine. One can do that even though his innovative logic, which he incorporated into the circuits and which is the stuff that goes on inside the chips and other 'black boxes,' remains invisible. It may be an exceptional case, but in at least this instance one can 'read' a computer, and museum curators can design public exhibits that exploit this.

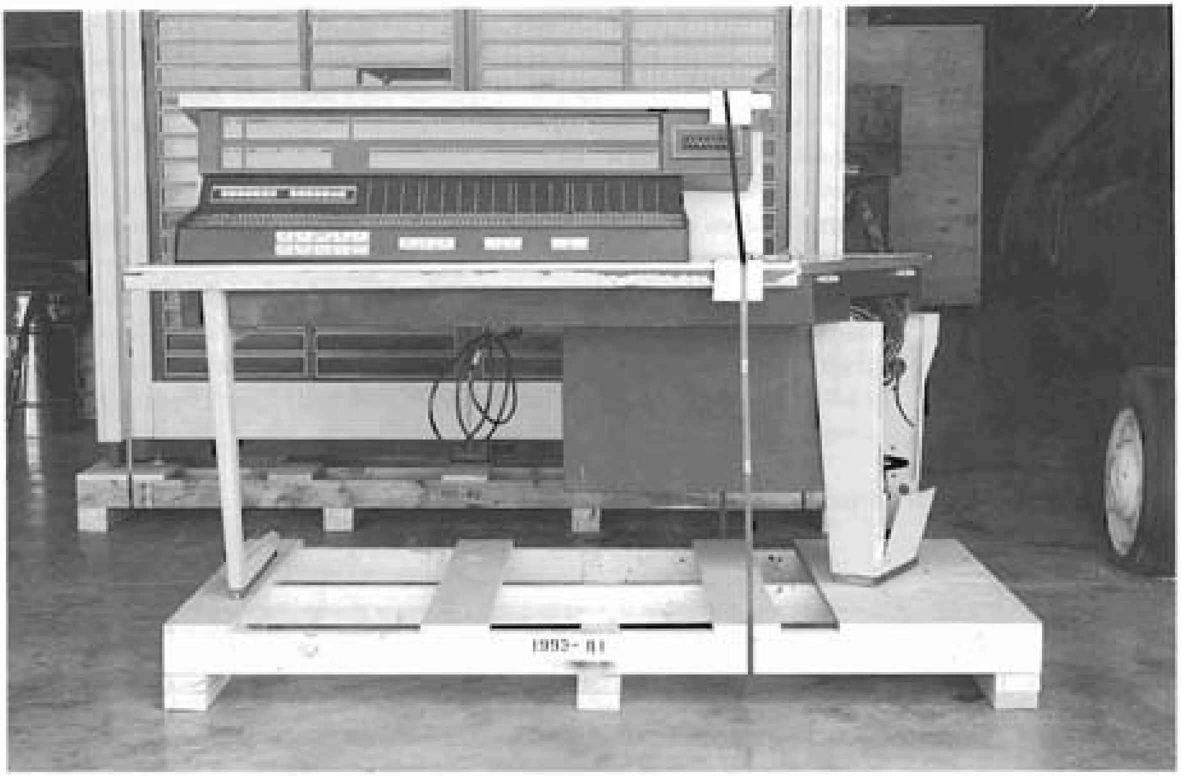
That leads, finally, to a mystery that I encountered when I recently acquired a computer from the U.S. Air Force. The computer was a Control Data CDC-3800, and it was offered to the National Air and Space Museum by the Air Force's Onizuka Air Force Base, located in Sunnyvale, California. When I received this offer I accepted it almost immediately. That was not because I knew anything about the computer—I didn't—but because of the place where it was located. I knew

Figure 7. A CRAY-2, in front of its disk farm. The tubes in the front of the photo held the inert cooling liquid, which flowed through and around the processor circuits. (Credit: Cray Research, Inc.)

Figure 8. A CRAY-1, serial #14, on display at the National Air and Space Museum, in a gallery devoted to the use of computers in aerospace. (Photo: Smithsonian Institution, # 92–15054–6)

however that Onizuka Air Force Base, named after an astronaut killed in the *Challenger* accident, was a base in name only. In fact it is a large, rectangular, blue building, whose very existence was classified throughout the Cold War. It remained secret in spite of the fact that the building is right next to a busy freeway in the middle of Silicon Valley, and that investigative journalists had already described the building and its functions, giving it the popular name the 'Blue Cube.'[5] It was the place where U.S. intelligence satellites were controlled and operated. The very existence of these programs was kept classified throughout the Cold War years. Even today these activities remain among those classified as black: their budgets are buried within other appropriations, to make it difficult for anyone without the proper clearance to know what is going on.

The computer being offered to the Air & Space Museum had been involved in these activities.[6] Given the importance of satellite reconnaissance, and the scarcity of any artifacts related to it in the Smithsonian's collections, it seemed appropriate to accept this offer regardless of whatever technical innovations the CDC-3800 had or did not have. We knew



how difficult it was to exhibit computer hardware in our museum. We also knew that the public was familiar with these activities, through venues like Tom Clancy novels and Hollywood movies starring actors like Harrison Ford. These fictitious accounts are far removed from what really happens, but they do provide a way, however imperfect, to bring a visually-uninteresting object to life.

Figure 9. The Air Force's CDC-3800, now in storage at the National Air and Space Museum's Paul E. Garber Facility in Silver Hill, Maryland. Plans are to exhibit the computer, in the context of reconnaissance satellites and other military programs, at the museum's new facility at Dulles Airport. (Credit: NASM)

As might be expected, I received little in the way of documentation when I acquired the computer.[7] Nor was I able to find much about it in the published descriptions of Control Data products, although information is available about its civilian counterpart, the CDC 3600. An informal query posted on an Internet discussion group turned up several retired CDC employees who believe that Seymour Cray was involved with the design of the CDC-3800, but they are not certain. The one technical description of the CDC-3600 that was published at the time of its introduction, however, indicates that it had a different architecture from the Cray-designed CDC-6600, and that it was related to CDC computers that Seymour had nothing to do with.[8]

So I conclude with a question: did Seymour Cray design the CDC-3800? Cray was employed at CDC at the time, and he could have been involved in its design at some stage. I have done some preliminary research, but I have not had an opportunity to do more detailed archival research that might establish its pedigree. But to harken back to the Computer Museum intern's reading of the NTDS: can one tell simply by looking at it? The computer is housed in a series of rectangular boxes. The circuits are densely packed, with wire-wrapped connections among the circuit boards. The frame is massive—the nameplate alone weighs as much as the computer on my desk! Does that make it a Cray machine? Current plans are to exhibit the computer as part of the opening of the Air and Space Museum's Extension, at Dulles Airport, sometime around 2003. When that exhibit opens, I hope to develop this theme in the labels for the computer, and thereby bring the visitor into the topic. By then I expect to have looked at the archival record and thus know the answer based on written texts. Regardless of what I find, I intend to keep a reading of the text of the machine itself.

Notes

1. Eugene S. Ferguson, 'The Mind's Eye: Nonverbal Thought in Technology,' *Science*, 197 (26 August 1977): 827–836. Relevant to this paper is the fact that when Ferguson revised and expanded that paper into a book, *Engineering and the Mind's Eye*, (Cambridge, MA, 1992), he added a discussion about the introduction of computers, especially of the practice of computer-aided-design (CAD), expressing concern that insofar as it reduced emphasis on the non-verbal, CAD was causing the practice of engineering great harm.
2. As in, e.g. the well-known series of books by Nathan Rosenberg: *Inside the Black Box*, (1982), and *Exploring the Black Box*, (1994).
3. Donald MacKenzie, 'The Influence of the Los Alamos and Livermore National Laboratories on the Development of Supercomputing,' *Annals of the History of Computing*, 13/2 (1991): 179–201.
4. Donald MacKenzie, *Knowing Machines: Essays on Technical Change* (Cambridge, MA, 1996), Chapter 6, with Boelie Elzen.
5. William E. Burrows, *Deep Black: Space Espionage and National Security* (New York, 1986). Burrows says very little about what happens in the 'Big Blue Cube,' which he identifies as the Air Force's Satellite Control Facility. Since the end of the Cold War other more detailed accounts have appeared. Beginning around 1990 the operations at the facility were transferred to a 'Consolidated' Space Operations Center in Colorado, although Onizuka AFB remained active. Burrows claims that the reason for the transfer was that the facility is located on an active earthquake fault, and it is vulnerable to a terrorist who could simply drive up to it along U.S. Highway 101. I do not find either argument convincing.
6. James B. Schultz, 'Inside the Blue Cube: USAF Modernizes Satellite Tracking Network,' *Defense Electronics* (April 1983): 52–59.
7. I was allowed inside the facility, where I saw the computer installed in an ordinary mainframe computer room, just prior to its being declared surplus. I do not have a security clearance.
8. Charles T. Casale, 'Planning the 3600,' *AFIPS Conference Proceedings*, vol. 22, Fall Joint Computer Conference (1962), pp. 73–85. A talk given by C. Gordon Bell in November 1997, which he posted on the World Wide Web, stated that 'Cray worked on the circuitry for the 3600 en route to the 6600.' (http://www.research.microsoft.com/research/barc/Gbell/craytalk/index.htm)