The TX-2 Computer and Sketchpad

Early computer technology at Lincoln Laboratory led to computer graphics and the functionality of your touchpad.

Some recollections by Ivan Sutherland of MIT and Lincoln Laboratory, 1960 to 1963

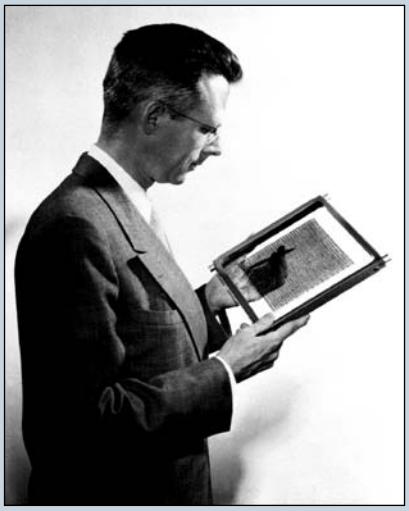
I first joined Lincoln Laboratory as an intern for the summer of 1960. Having decided to move from Caltech where I got a master's degree to MIT for my PhD program, I had applied to Lincoln in the early spring. It got to be late spring and I had heard nothing, a silence that caused grave concern because my wife, Marcia, was expecting our first in August.

One of my early assignments at Lincoln was to characterize a tunnel diode, newly invented and not yet well understood. I recall wrapping a dozen turns of wire around a pencil to make an inductor, which, when connected in series with the tunnel diode and a single dry cell, made a fine relaxation oscillator. Moreover, I recall that it produced about 50 MHz, which at the time seemed to me a very high frequency indeed. I also recall seeing the sawtooth waveform on an oscilloscope. That was the day I lost interest in ham radio, trading my interest in linear circuits for the appeal of nonlinear devices.

I wanted to use the TX-2 computer for my thesis work—what later became Sketchpad. I went to Wes Clark and described the project I had in mind. He puffed a few puffs on his pipe, but failed to give me an answer, so I asked if he needed more time to think about his decision. After a few more puffs, he said, "No." My crestfallen look must have caused him quickly to add that the "no" was no more time. His answer to my plan was "Yes." I was on my way to my thesis. It was only much later that Wes and I became good friends rather than mentor and pupil, though some of his mentor role remains with me to this day. Wes once told me that he designed TX-2 for Sketchpad long before I ever came to Lincoln. I guess he was confident that "if you build it, they will come."

I found a bug in the logic of the "Lincoln writer." The Lincoln writer was a Laboratory-built terminal device consisting of an electric typewriter with lots of special characters and two keyboards, one for upper

TX-2 computer



Jay Forrester is holding a magnetic-core memory .

TX-2 was an experimental digital computer created at MIT in 1958. It was one of a few first-generation large electronic digital computers in which transistors largely supplanted vacuum tubes. It was designed to facilitate and enhance real-time human-computer interaction. When first implemented, TX-2 had inherited the ferrite-core memory from its predecessor TX-0 (there was no TX-1). It also had two other random-access memory modules that could work concurrently to provide increased computing speeds. TX-2 was an experimental tool to test many techniques and devices, among which were a magnetic-core memory unit and the first thin-magnetic-film memory unit.

William Kantrowitz, a systems programmer on the TX-2 computer, provides the following list of some of the highlights of the TX-2 computer.

- Much of computer graphics [Sketchpad] began on TX-2.
- Early pioneering speech research was carried out on TX-2.
- TX-2 had one of the first, if not the first, two-level memory paging systems.
- Pioneering work in large memories was done with TX-2.
- The Advanced Research Projects Agency network (ARPANet) derived from experiments on TX-2 with a prototype net between TX-2 and a computer at System Development Corporation in California.
- The feasibility of using the ARPANet for packet speech transmission was first demonstrated on TX-2.

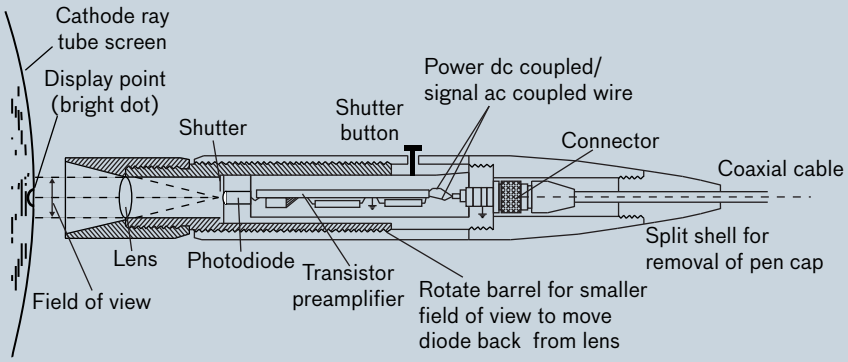
case and one for lower case. There were about a dozen Lincoln writers in the Laboratory, each built into a small table with casters. The bug, as I recall it, had to do with a particular problem with changing case. On the tape a "change to uppercase" mark served to herald each string of uppercase characters, and a "change to lowercase" mark served to herald each string of lowercase characters. I think the bug was that the reset worked from the keyboard but not when one typed from paper tape. I went to my boss of the time, Jack Mitchell, and reported the bug. I was surprised to hear him ask me to propose a fix. I was even more surprised when my proposed fix, which involved half a dozen additional relays, was adopted and built into all Lincoln writers. Although I had a master's degree from Caltech, my engineering skill had never before been taken seriously; the memory remains vivid. Part of education is learning to take one's place in professional life.

Although enormous both in physical size and in capacity for its day, TX-2 operated like a personal computer. Users sat at the console and debugged code or did experi-

Sketchpad

The Sketchpad system was the first graphical computer interface. It made it possible for a man and a computer to converse rapidly through the medium of line drawings. Heretofore, most interaction between man and computers had been slowed down by the need to reduce all communication to written statements that could be typed; in the past, we had been writing letters to, rather than conferring with, our computers. For many types of communication, such as describing the shape of a mechanical part or the connections of an electrical circuit, typed statements can prove cumbersome. The Sketchpad system, by eliminating typed statements in favor of line drawings, opened up a new area of man-machine communication. The currently used graphical user interface, or GUI, was based on Sketchpad.

Ivan Sutherland is shown working with Sketchpad. The lightpen, shown below, and the keyboard function control are the precursors for the mouse and right and left mouse-clicks prevalent today.



ments online. Computer time seemed most available in the wee hours of the morning, so I was up at least two mornings a week early enough to get to Lincoln for my 3:00 to 6:00 a.m. computer time slot. Marcia, I recall, regularly got up long enough to see me off, and later woke our two young children. It may be that my pleasant early morning experiences with TX-2 conditioned me to being an early riser, a property I retain to this day. The cafeteria served a nice breakfast starting about when I finished my morning debug session, and I came to love sunrises.

There was a Xerographic printer on TX-2. It printed on a roll of paper about six inches wide using a "charactron" cathode ray tube with a stencil inside to shape its electron beam into the many characters we used. The print wasn't great, but it could print all our special characters at reasonably good speed. This was, of course, long before xerographic computer printers were common. The group at Lincoln had convinced Xerox to put this printer together as a one-off special. The result was itself a bit experimental, and though it printed OK, xerography requires heat to fuse the powder deposited electrostatically on the paper. Sadly, if the paper jammed, it would sometimes catch fire, and if it didn't jam, it often emerged highly charged with static electricity. The paper dropped from the printer into a large steel bin with a sturdy steel lid to use in case of fire.

On the day I was to demonstrate Sketchpad for the first time to a group of visiting dignitaries, Tom Stockebrand, a fellow Caltech graduate who was about as far from formal in dress as a person can be, asked if he could hang around to watch. Fred Frick, who was then the director of the lab, looked at Tom and said, "Well, Tom, I see you're wearing shoes today, so I guess it's OK for you to stay." The demo went well, as I recall.

Every Wednesday, TX-2 changed a little. The hardware folk would add new features, improve performance, or do repair. We software types got to use the sometimes problematic result. Can you imagine the concern that would spread in the software group when a rumor went around that, today, the multiply operation might not work properly?

Hardware bugs also happened, through component or engineering failure; TX-2 was, after all, an experimental computer. The quickest way to get a bug fixed was to write a very simple program that failed in spite of obvious correctness, and the easiest way to "explain" this bug to the hardware engineers was to show them a Polaroid photograph of the panel of toggle switches that "stored" 24 words of 38 bits each and the console lights. Leaving a program in toggle switch memory that should obviously work, but failed, was a sure way to get the hardware people to fix a bug.

Many of my memories are about great people. Larry Roberts, a fellow graduate student at MIT and at Lincoln, was using TX-2 for early work on image processing. I once mentioned to Larry a remarkable set of musical tones developed at Bell Laboratories. Each tone seemed, subjectively, to be higher in pitch than the one before, yet, like Escher's staircase, the set of tones closed on itself. I failed to mention to Larry that the Bell people had made a series of discrete tones, a fairly easy task. Seeking to duplicate their work, Larry wrote a much more difficult program to make TX-2 produce a continuously rising tone, a siren with ever-rising pitch. Larry's siren went up and up in pitch, octave after octave, until it should have been audible only to dogs and not to people. What a noise. Larry reported to me that the guards rushed into the computer room when his program first ran successfully. No such siren had ever been heard in the Laboratory, or anywhere else, and it could only indicate a disaster requiring the attention of Lincoln's alert guard force!

I left the Laboratory in 1963, my fresh PhD in hand. TX-2 lived on. Over the years, it grew ever more capable each Wednesday. It got more and better memory. It got more input and output devices. It got a time-sharing system to participate in what was then another new field of computing: serving multiple users. I think it is very significant that TX-2 had a useful life of over 20 years. Few, if any, of today's computers can hope to be useful that long, and, indeed, only a very few whole families of computers have had a similarly long useful life.

—Ivan Sutherland

Sutherland started his career at Lincoln Laboratory as an MIT graduate student. After receiving his PhD, he headed the Advanced Research Project Agency's Information Processing Techniques Office. Subsequent to that, he worked for Harvard University, the University of Utah, California Institute of Technology, and Sun Microsystems. He is currently a visiting scientist at Portland State University where, with his wife Marly Roncken, he is leading the research in asynchronous systems.