Personal Reflections on the History of the Computer History Museum

Len Shustek, 26 September 2014, V1.0

I came to history late in life because I didn't much like it as a kid. My first career path after getting my PhD in Computer Science at Stanford was academic, and then for 16 years I was smitten by the entrepreneurship bug and co-founded two computer networking companies.

In 1994 I took a break from the startup world and returned to academia. I taught EE282 at Stanford, the same graduate course in computer architecture that I had taken 23 years earlier from the legendary Ed McCluskey. Of course the field had progressed enormously, and much of the material was new.

ELECTRICAL ENGINEERI

EE282
Computer Architecture and Organization

Course Objective

To introduce the design principles and to discuss the design issues of associated with microprocessor based systems.

Course Description

Structure of systems using processors, memories, input/output (I/O) devices, and I/O interfaces as building blocks. Computer system instruction set design and implementation, including memory hierarchies and pipelining. Issues and tradeoffs involved in the design of computer system architectures with respect to the design of instruction sets.

Prerequisites

EE182

Topics

1. Architecture design principles (2 classes)
2. Measuring cost and performance (2 classes)
3. Instruction set design (4 classes)
4. Processor implementation techniques (1 class)
5. Pipelining (4 classes)
6. Memory Hierarchies (4 classes)
7. I/O systems (2 classes)

Instructor

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But I also discovered that, in the interim, history of the field had been largely removed from the curriculum. In 1971 we learned about memory paging by reading the original papers about the first computer that used it, the Ferranti/Manchester Atlas. Alas, in 1994 there were no historical papers on the reading list.

One-Level Storage System*

T. KILBURN†, D. B. G. EDWARDS†, M. J. LANIGAN†, AND F. H. SUMNER†

Summary—After a brief survey of the basic Atlas machine, the paper describes an automatic system which in principle can be applied to any combination of two storage systems so that the combination can be regarded by the machine user as a single level. The actual system described relates to a fast core store-drum combination. The effect of the system on instruction times is illustrated, and the tape transfer system is also introduced since it fits basically in through the same hardware. The scheme incorporates a "learning" program, a technique which can be of greater importance in future computers.

I. Introduction

IN A UNIVERSAL high-speed digital computer it is necessary to have a large-capacity fast-access main store. While more efficient operation of the computer can be achieved by making this store all of one type, this step is scarcely practical for the storage capacities now being considered. For example, on Atlas it is possible to address 10^6 words in the main store. In practice on the first installation at Manchester University a total of 10^6 words are provided, but though it is just technically feasible to make this in one level it is much more economical to provide a core store (16,000 words) and drum (96,000 words) combination.

Atlas is a machine which operates its peripheral equipment on a time division basis, the equipment "interrupting" the normal main program when it requires attention. Organization of the peripheral equipment is also done by program so that many programs can be contained in the store of the machine at the same time. This technique can also be extended to include several main programs as well as the smaller subroutines used for controlling peripherals. For these reasons as well as the fact that some orders take a variable time depending on the exact numbers involved, it is not really feasible to "optimum" program transfers of information between the two levels of store, *i.e.*, core store and drum, in order to eliminate the long drum access time of 6 msec. Hence a system has been devised to make the

* Received September 11, 1961.
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That seemed like a shame. After all, physicists learn about Newton, chemists learn about Lavoisier – why shouldn't computer scientists learn about Babbage, Turing, Von Neumann, and all the rest?

I couldn't single-handedly change the curriculum, so I looked for another way to bring history back. It seemed to me that the story could be told by a museum instead, and to a wider audience than computer science students. Silicon Valley, where I then lived, had become the center of the world for computers, so that was the natural place for it.

When my teaching gig was over in 1995, I began seriously talking about starting a computer museum, and worked on plans for its funding, location, and activities. I thought I would have to go it alone, but that was fine; I was used to startups. I wrote a series of white papers making the case for a museum (www.computerhistory.org/...), and shopped it around.

The Case for a Silicon Valley Computer Museum

The computer was not invented in the San Francisco Bay area, nor are most of the world's computers built here. But few would argue with Silicon Valley's claim to the title of intellectual capital of the computer business. The confluence of established companies, startups, venture capital firms, technology-friendly universities, and media coverage has caused the center of gravity to shift to this area.

Perhaps because the early development of computers was centered elsewhere, an appreciation of the history of computers has not been much expressed here until recently. That has changed, however, and the objective of this paper is to show that **now is the time, and Silicon Valley is the place, to establish a major computer history center and the world's premier display collection of computer memorabilia**.

Surely, I thought, there must be other dedicated computer museums that I could model ours after. If we were starting a car museum, there would be hundreds to look at.

There weren't. I visited the Smithsonian and was disappointed. I discovered there was only one potential model: The Computer Museum in Boston. In 1996 I visited TCM, and met Gwen Bell, and learned its story.

TCM had opened in 1979 in Marlboro as the "Digital Computer Museum" to do exactly what I wanted to do, but in the intervening years, after the move to downtown Boston, it had lost its way. The computer industry had largely left the area, and funding for computing history there was hard to come by. The museum was gradually morphing into a kids-oriented science center, competing with the much-larger Museum of Science in Boston. The back rooms Gwen showed me still contained a valuable collection of historic artifacts, but almost nobody got to see them. The big attraction was a larger-than-life "walk-through" personal computer that kids could climb on.

After I returned to California, Gordon came to visit me in my Menlo Park office with Carol Welsh, the only west coast employee of TCM. We spoke for several hours. Gwen and Gordon were still clearly devoted to TCM's original history mission, and were disturbed by the changes. We began to hatch a plot.

Gordon basically said, "Don't start your own museum. Reboot what we started in Boston, but this time in Silicon Valley." Given Gordon's reputation and the headstart that TCM represented, it didn't take me long to accept that offer.

I abandoned my plans to start my own museum. Instead, I joined the board of Boston-based TCM specifically to found a subsidiary of it in Silicon Valley dedicated to computing history. We clearly saw the handwriting on the wall: the museum in Boston was headed downhill, and the Silicon Valley outpost, which we called "The Computer Museum History Center", was going to be the museum's future.

We hired Dag Spicer, a Stanford graduate student in the history of technology, as our first curator. We rented three temporary offices in a Santa Clara office park for Carol, Dag, Gwen, and me, and started planning.

Our immediate highest priority was to protect the collection from the problems that were sure to develop in Boston. I arranged free warehouse space at Moffett Field through a friend at NASA Ames, and in the fall of 1996 we loaded four full-size tractor-trailers and moved thousands of the most important artifacts of the computing revolution to the west coast. We filled most of Building 126 (a "temporary" building with a leaky roof dating from World War II), and also put some objects in the giant dirigible hangar next door.

We got dozens of volunteers involved, spent days cleaning and organizing, and created an amateurish but impressive "Visible Storage" exhibit.

In the meantime we plotted the museum's future. Gwen Bell, who had run the Boston museum in the early days but now lived mostly in Los Altos, became my personal guiding light throughout the process. We not only did all our own fundraising to support the operation, but we also had to pay a 25% tithe on what we raised back to the "mother ship" in Boston.

In 1997 The Computer Museum published a special version of its newsletter highlighting the establishment of the west coast History Center. It included a profile of me, which has special personal significance because one of the museum supporters on the mailing list, Donna Dubinsky, read it and decided she was interested in meeting me. Three years later we were married!

The Computer Museum NEWS

Winter 1997

Special History Center Issue

Museum Opens Computer History Center in Silicon Valley

On an Indian-summer day last September in Mountain View, Calif., four 18-wheelers completed their cross-country trek to deliver 100,000 pounds, or one-half, of the Museum's collection from Boston to the NASA Ames Research Center. The Museum was not turning its prize jewels over to the government, but, rather, NASA was generously donating valuable warehouse space for the collections. The Museum was taking a giant leap forward in advancing the third leg of its mission to be "an international resource for research into the history of computing." The warehouse space on NASA's Moffett Field was the beginning of the creation of The Computer Museum History Center.

The Computer Museum History Center's charter is to continue to build the 15-year-old collection proactively and be a resource for research into the history of computing. At the same time, the Center and the Museum will liberally share the collections, and a historical context will continue to infuse Boston exhibits. The collection is also available for use by publications as well as scholars, educators, researchers, engineers and journalists.

The Epiphany

Initial underwriting for the Center was provided by Gwen and Gordon Bell and Dr. Leonard J. Shustek. Shustek is co-founder and fellow of Network General Corporation, a Computer Museum board member, and serves as chairman of the Center. Shustek became involved in the History Center project, donating time and resources, because of a need he discovered while teaching a computer science course at Stanford University. "Once a week I would bring a historical 'show-and-tell' item to my class, like a vacuum-tube module or a core plane, and it produced puzzled but interested faces," Shustek says. "I realized that the history of computers is no longer being learned, not even by the specialists-to-be. I had an epiphany: In a generation we could lose the knowledge of how the computer revolution came to be, unless we act to preserve it."

Shustek joined the "work in progress," playing a key role in establishing the History Center. He was at the Moffett Field warehouse—Building 126, a former furniture showroom—the day the moving vans arrived. Taking in the collection was a back-breaking reminder of how far the industry has come. All the raw processing power in those four vans can now be held in two hands.

Collection Highlights

Some of The Computer Museum History Center's collection was donated by NASA Ames, such as the ILLIAC IV supercomputer and Robert Morris' Worm. Artifacts include a complete collection of Seymour Cray's computers from NTDS 17 (1957) to the Cray 1 (1976); Whirlwind (1951); UNIVAC 1 (1952); the PDP-1 with original *SpaceWar* game (1962); and more than 100 different early personal computers. Recent additions include the original MIPS wafer manufactured at Stanford University and Frederico Faggin's prototype of the Busicom calculator using Intel's 4004 chip, the first microprocessor.

The artifact collection has been organized into visible storage and is now available for viewing by appointment only. The rest of the collection is due to be moved within the year. Plans are in progress to identify a permanent Computer Museum History Center facility in Silicon Valley to house the collections, historic exhibitions, research and administrative offices.

After finding a permanent facility, the Center will present artifact-rich, *Scientific American*-level exhibits directed toward a

(continued on p.4)

Photograph: © Louis Fabian Bachrach

The Museum's collection has plenty of room to spread out in its new home at NASA Ames Research Center.

Meet the Board: LEN SHUSTEK

For Dr. Leonard Shustek, a step into the past led him to discover the riches of The Computer Museum. "Two years ago, I got to teach a course in computer architecture at Stanford that I had taken as a graduate student 23 years earlier," Shustek begins. "Needless to say, there were a few changes in content that made reading my old notes less than adequate preparation. But I managed to scramble fast enough to stay a couple of weeks ahead of the students—most of the time!

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After Shustek finished his teaching duties, he traveled around the country in search of institutions that were preserving computer history. "It didn't take long to discover TCM and the 'buried treasure' in its archives," Shustek says. "After a discussion with Gwen and Gordon Bell, it took about a millisecond to accept their offer to help create the Computer History Center in order to expand and showcase the historical collection." Shustek's considerable talents were soon focused on getting The Computer Museum History Center started.

Fortunately for the Museum, the start-up phase was familiar to Shustek. Having earned undergraduate and Master's degrees in physics, and a second Master's along with a doctorate in physics, Shustek eventually moved from academia to test his skills in a "typical Silicon Valley garage start-up."

Shustek took a "temporary," eight-year leave of absence from teaching computer science at Carnegie-Mellon University in 1978 to found Nestar Systems, an early entrant in the network client/server computing business using personal computers as workstations. "It was a classic case in which a couple of academic escapees who know a little about engineering and nothing about business get to learn on the job by making mistakes," Shustek says in typically understated style. "Unfortunately, we made enough of them so that the company, although it grew to 125 employees, was never a success." Shustek adds with a smile, "We, of course, like to think it was because we were ahead of our time."

Photograph: © Louis Fabian Bachrach

Len Shustek has lent his talents to ramping up TCM's History Center.

Nestar was a fortuitous experience. Eight years later, Shustek tried again with some of the same colleagues. He co-founded Network General Corporation, which became an almost overnight success in network analysis tools for communications networks. Network General (NASDAQ: NETG) now has 700 employees and revenues of $180 million a year. Shustek now serves as Network General Fellow, which he describes as "a part-time position of great honor and no responsibility."

TCM: What's your wish for TCM?

Shustek: For it to become recognized worldwide as the leading institution devoted to explaining computer technology and preserving its history. Since we're well on the way to that goal, I feel very optimistic about the future of TCM.

TCM: What is one of the biggest challenges facing the industry?

Shustek: We started with the Hardware Era, progressed through the Software Era, and are now in the Information Era. The accumulated knowledge of civilization will from now on be stored using computer technology. That makes us responsible to provide universal access, freedom from censorship, efficient searches, clever organization, fair intellectual and commercial property rights, and unlimited archival storage, all in a way that makes economic sense. That's challenge enough for a lot of new start-ups!

LEN SHUSTEK: *Short Takes*

First computer:
An IBM 650, which was a vacuum-tube drum-memory computer. It was an early '60s effort by IBM to introduce New York high school kids to computers in the hopes of making them computer users instead of "juvenile delinquents." (I guess it worked; I never even *owned* a switchblade!)

Other philanthropic pursuits:
• Supporting the Packard Children's Hospital at Stanford in the Starbright project, which provides linked interactive virtual-reality playgrounds to seriously ill children who can't use real playgrounds.

• Establishing a group home in the south Bay Area for retarded young adults who have never before lived away from their parents.

Biggest technology gripe:
What annoys me most, especially now that the computer is a consumer product, is how difficult it is for most people to use. We can do better!

Phone or e-mail:
E-mail, almost always.

Recreation:
Hiking, bicycling, SCUBA diving, and riding a motorcycle in order to prove that I'm having my mid-life crisis on schedule.

Best advice ever received:
Always initialize all your variables. (Does anyone remember that the IBM 7040 used bad parity to detect uninitialized variables? Now there's a bit of computer history trivia!)

TCM: What was your most amazing "find" on the Internet?

Shustek: My sister, whom I had never met! I knew nothing about my older half-sister except that she might exist. We discovered each other through an Internet newsgroup last year, and we have since met—both in cyberspace and in person. Since we share some genes, it came as no surprise that she's in the computer business too. We've each had a lifetime that we're gradually filling each other in on.

In 1999 the scene played out just as we had predicted: The Computer Museum in Boston closed to the public, and the corporation was dissolved. We incorporated as a new California non-profit and, after duly petitioning the Attorney General of Massachusetts, became the owner of the collection we had moved out west three years earlier. Possession, in this case, was more than 9/10ths of the law.

We kept the 7 trustees[1] (out of 19) from the Boston corporation who were still fans of the history mission. We built a stronger board by adding 11 people[2], many of whom who had been involved with TCM earlier but had become disaffected. We hired more staff, ramped up fundraising, and started the process of becoming a real museum.

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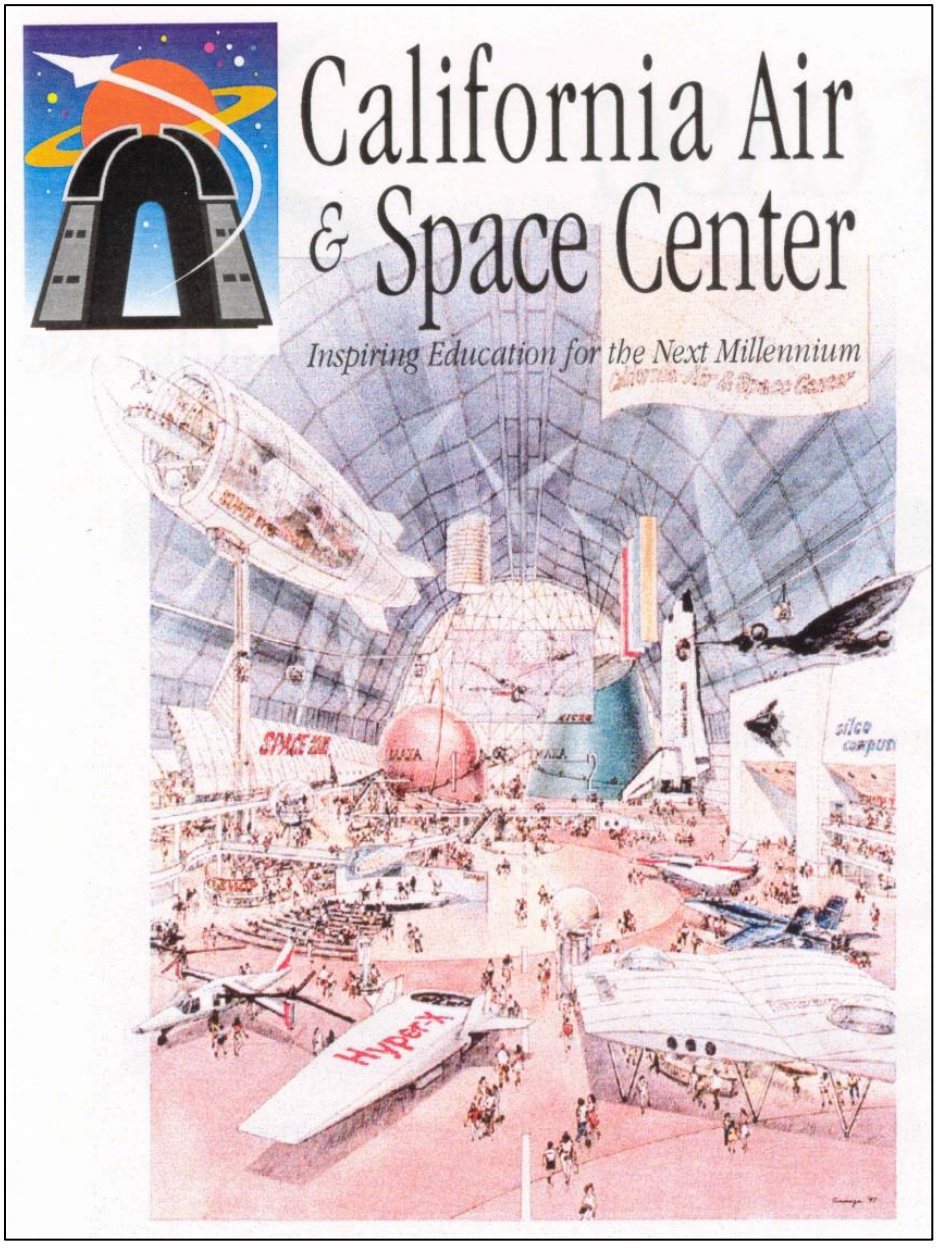
[1] Sam Fuller, Gardner Hendrie, Dave House, Christine Hughes, Steve Kirsch, John Shoch, Len Shustek

[2] Dave Anderson, Gordon Bell, Andy Cunningham, Peter Hirshberg, Chuck House Ike Nassi, Suhas Patil, Bernard Peuto, Bill Poduska, Grant Saviers, Pierluigi Zappacosta.

With the collection and governance in place, the next question was where the permanent facility should be. I had some initially promising conversations with Stanford University about locating on campus, but there were all sorts of complications with that.

Back at Moffett Field, NASA was planning to convert tens of acres into a research park whose central feature would be a public California Air and Space Center built inside the dirigible hangar.



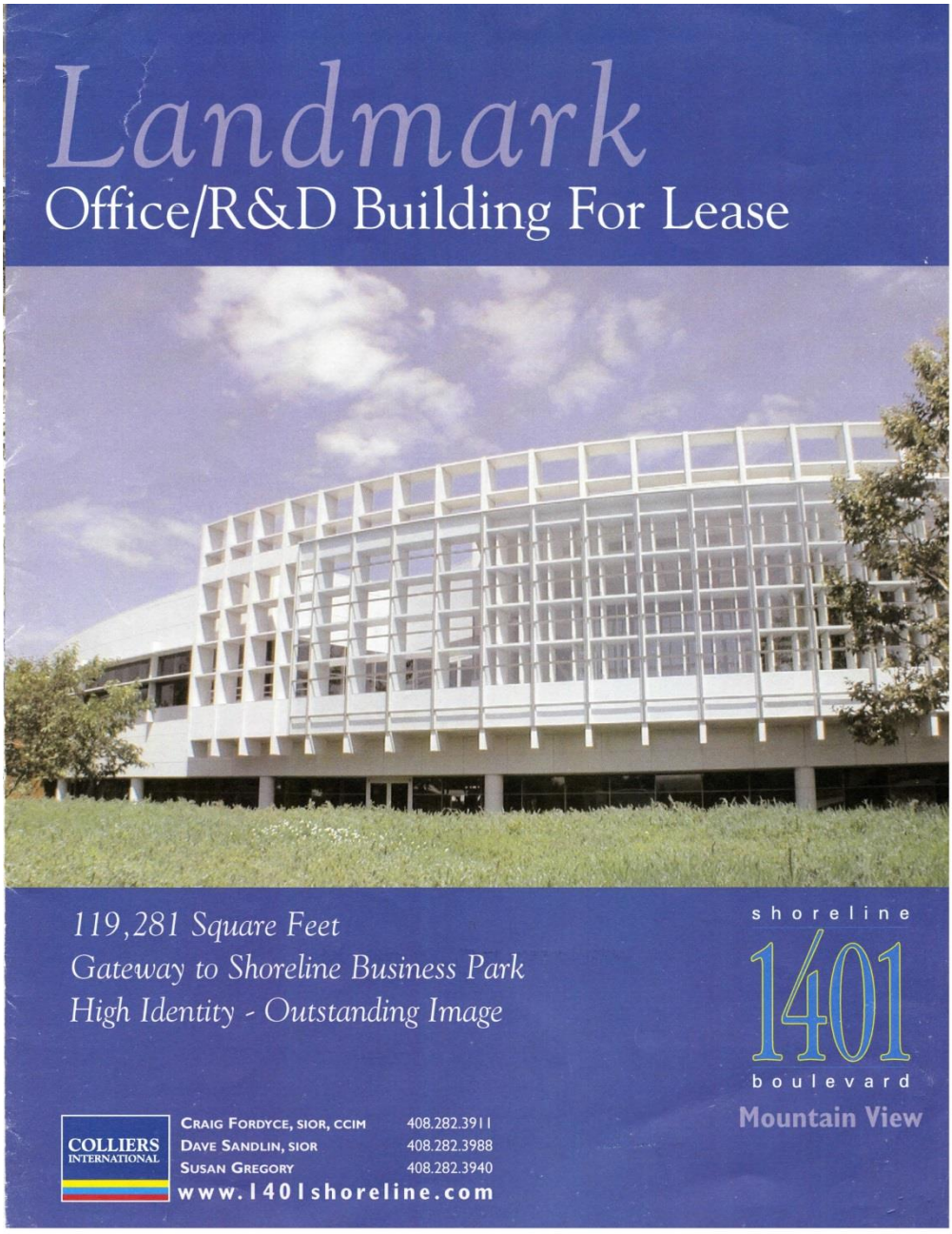
NASA offered us a ground lease on two acres right in front of the hangar to build our museum on. It was an appealing prospect, because museums that cluster do well together. That became our plan of record.

We decided to execute in two phases. The first was to build a temporary "beta" building to house the collection and Visible Storage.

The second phase would be to build the permanent facility and convert the beta building into warehouse storage. We ran an architectural competition and got impressive submissions, complete with foam-core models, from three well-known architects.

Two things happened to derail that grand plan. The first was our discovery, which in retrospect should have been obvious, that NASA moves with the speed of a federal bureaucracy. Being startup folks, we didn't have the patience for that. Fifteen years later, in 2014, the NASA Moffett research park has yet to be built.

The second was economic: the 2001 dot-com bust happened, and suddenly there were attractive properties available all over Silicon Valley. There were dozens of "see-through" buildings in every commercial area from San Jose to San Francisco. We put our building plans on hold, did a search, and found the ideal property: the former sales and marketing headquarters of computer maker Silicon Graphics. It had been sold to a real estate investment company whose plan was to lease it until market prices came back up.



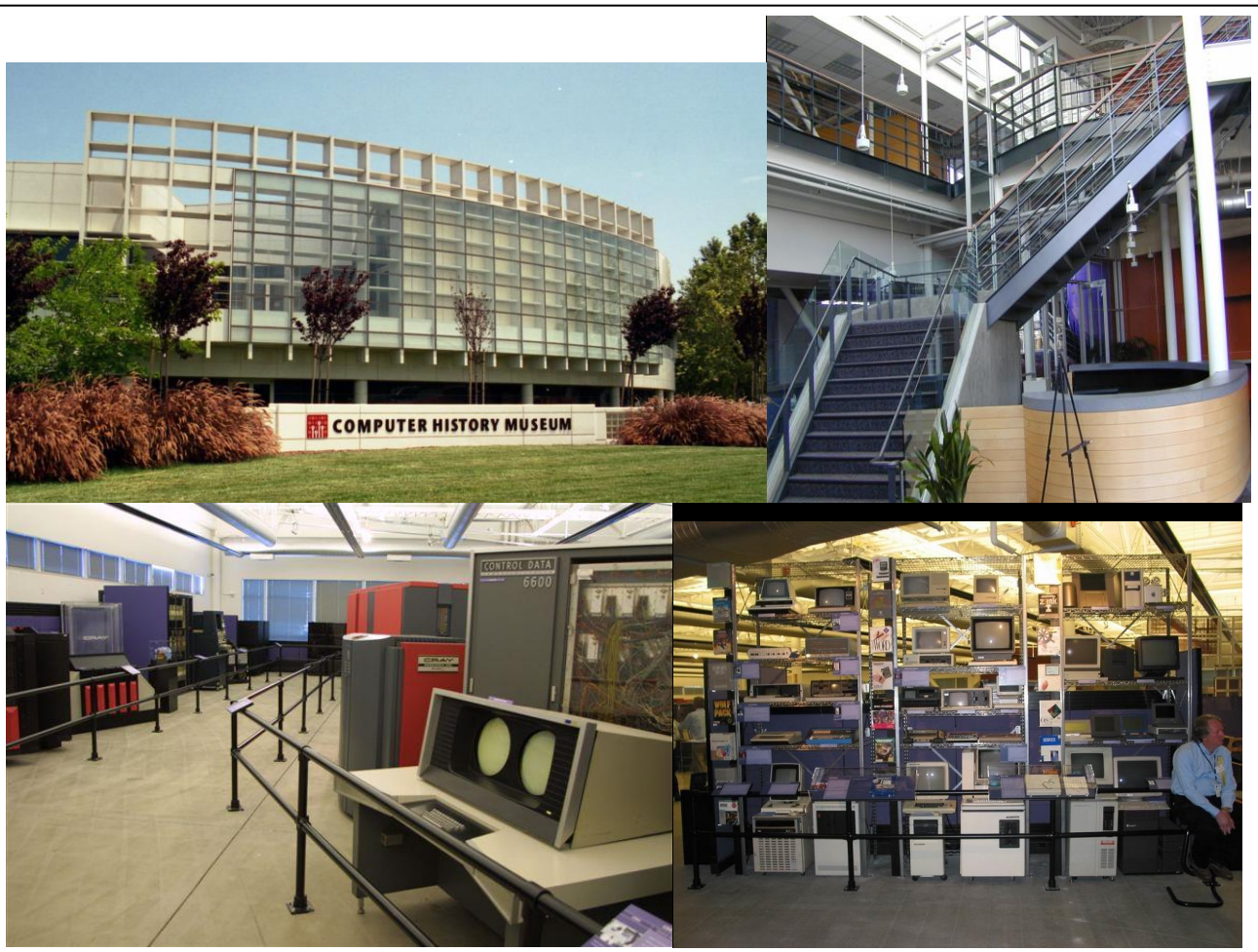
We negotiated with the seller and got them to agree to sell us the land and building right then for $25M. But where were we going to get the money?

Fundraising actually was going well, in large part due to the generous board and the spectacular fundraising abilities of Donna Dubinsky, who by then was a trustee. But in order to build an endowment that would help insure the long-term future of the institution, we were adhering to a self-imposed "50/50 rule" that reserved half of every capital campaign dollar for the endowment. We didn't yet have $25M of cash in the building fund, and we would have lost the building by waiting until we did.

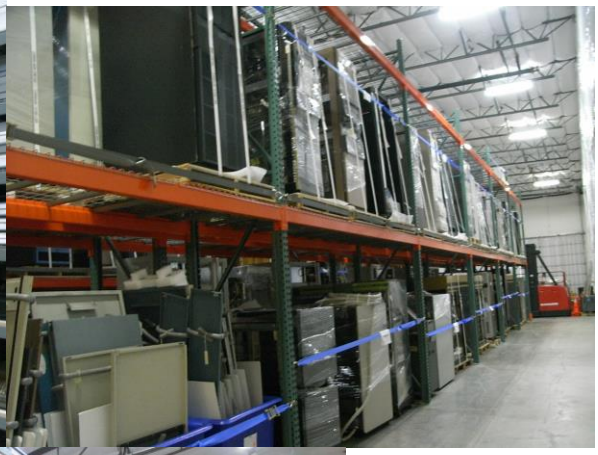
The solution was to issue a $25M tax-free bond, which non-profits are entitled to do through a local government agency. The problem was to convince the board that it was a good idea.

Many of the trustees had scar tissue from the TCM Boston experience, where a capital campaign to retire the mortgage of less than a million dollar had failed. The board meeting on June 21, 2002 was the most difficult and tense one I had ever chaired, but in the end we got board approval, issued the bond, and purchased the building in October 2002.

We made building modifications, moved the collection out of Moffett Field warehouses, and created, thanks to our amazing VP of Collections and Exhibits Kirsten Tashev, a much more professional version of Visible Storage.

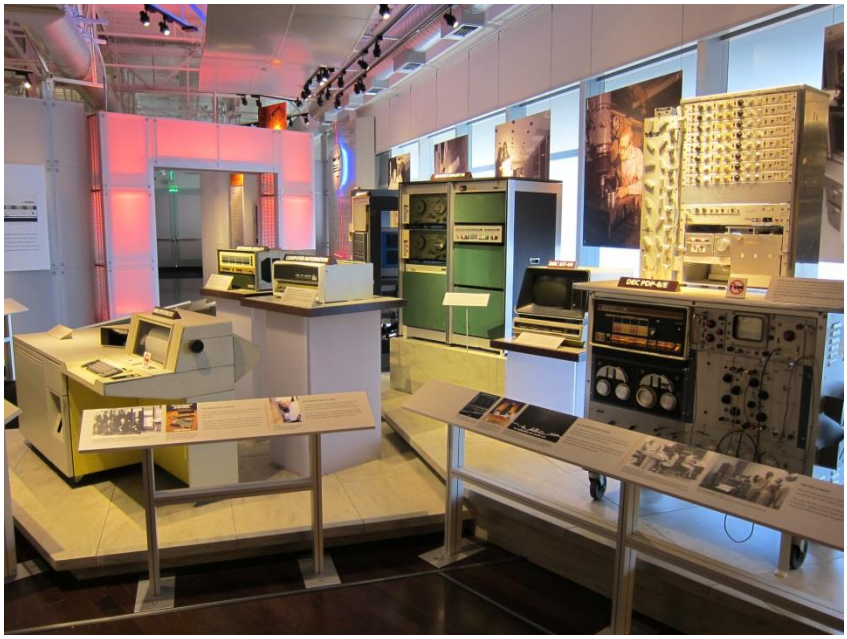


We continued to collect, of course. Eventually we ran out of room, so in 2008 we purchased a 25,000 square foot warehouse in Milpitas, 20 minutes away, to store the part of the growing collection that was not on display. For that, happily, we were able to pay cash!



While continuing to fundraise, we built temporary exhibits, like "Mastering The Game: A History of Computer Chess".

Finally, in 2011, we opened the large-scale permanent exhibit that we had been dreaming of for so many years: a 25,000 square foot extravaganza called "Revolution: The First 2000 Years of Computing".



The big exhibition has been spectacularly successful, but there have been many other accomplishments. We have restored old computers, built many temporary exhibits, created an innovative education program, put the Babbage Difference Engine on display, restarted the "Fellows" awards program, instituted a nationally-syndicated series of public programs, expanded the mission to include software, created a museum store and café, and put new energy behind the oral history program to preserve the first-person stories of the pioneers. And we are not at all finished; we have lots of plans for the future.

In the early days of this adventure I used to say "we're a startup with a 20-year history" because of our roots in Boston. In 2014 we're not a startup anymore. In fact, we've just passed the halfway point: the original "history mission" has now spent more time in California[3] than it did in Boston[4]. But TCM was our grandfather, and the source of our DNA.

There are many, many people who were important contributors to the Computer History Museum, and I apologize for not naming them all here. CHM has become an important world-class institution because of the amazing efforts over many years of the trustees, the staff, the volunteers, and our generous supporters. Thank you all!

-- Len Shustek, Chairman of the Board of Trustees of the Computer History Museum

[3] 19 years from 1996 to 2014
[4] 18 years from 1979 to 1996