Out of a Closet: The Early Years of The Computer * Museum

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5 May 2011

MSR-TR-2011-44

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* is either null or "History" recognizing the transformation of "The Computer Museum" to the "Computer History Museum."

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Abstract. The 2011 opening at the Computer History Museum of the world's largest and most complete physical and cyber exhibit of computing history marks the sixth stage of a public museum's evolution, which began in 1975 with a closet-sized exhibit in a Digital Equipment Corporation building, migrating to The Computer Museum, Boston. It now lives in an 119,000 square foot public home in Silicon Valley. This chance/luck driven evolution of an institution is due to the dedication and leadership of a few people who persuaded hundreds of others that the endeavor was worthwhile and needed their support. Gwen Bell, The Computer Museum's founding director, and Len Shustek, the founding chairman of the Computer History Museum were committed to its success! Behind nearly every artifact, exhibit, and pioneering effort is a story that the museum is dedicated to understand and tell. This is the story leading to the Computer History Museum.

Introduction

The Computer History Museum's opening of the *R|Evolution: The First 2000 Years of Computing* exhibit on 10 January 2011is the beginning of a new era for the Computer History Museum in realizing its mission: *"To preserve and present for posterity the artifacts and stories of the information age"*. The exhibit marks the sixth stage in the 35-year evolution of the museum, which began in a converted coat closet in Massachusetts and now lives in a beautiful 119,000 square foot public facility plus its 25,000 square foot climate controlled offsite artifact storage facility in California. A new computer class emerges about every 10 years, based on exponential hardware improvements and algorithm discoveries. The evolution of this world class collection, exhibition, and interpretation museum for computing, started in the early 1970s as a spin-out of The Computer Museum, Boston. This gestation time is far longer than for new computers and most company plans! The high rate of change coming from Moore's Law necessitates a sampling rate for collecting history of at least every year or two in order to capture the significant events in real time. Waiting 30 years to collect what will clearly be discarded and forgotten fails! This migration story1 of the museum from east to west and accelerating progress reflects the geographic shifts and exponential advances of computing itself, from mainframes to minicomputers to personal computing devices, and the eventual embedding of computers into everything.

The story of the museum's evolution began with Ken Olsen and me as collectors and supporters, and Dr. Gwen Bell's dedicated 20-year odyssey as the first director. We were all strongly motivated by the fact that no institution was seriously collecting computing artifacts for study, exhibition, and posterity. Our aspiration was not only to do the job, but to do it first and be the best.

Gwen established a classification taxonomy and acquisition criteria for the artifacts to be collected, and started building exhibits. She organized a series of lectures to capture the stories of key pioneers and pioneering efforts, which were published in the newly established *The Computer Museum Report* (TCM, 1980-1998). Fundamentally, she established all of the principles and practices that have remained, *almost* unchanged for the museum's first 30 years! Despite funding challenges and endless debates over what the institution should be and where it should be located, Gwen simply refused to let it die. She remained active until her 1998 illness prevented further involvement, by which time the museum was securely ensconced in Silicon Valley.

In 1995 Dr. Len Shustek picked up the baton with equal energy and commitment, and five years later added substantial support from his new wife, Donna Dubinsky. The progress of the museum was not only geographical, but also one of scale and vision. Nearly every dimension of support and activity increased significantly, including collecting, fundraising, and computer restorations.

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[1] Celebrating Brian Randell's 75th birthday. Professor Brian Randell has been a long-time friend and advisor to the museums, starting as the first Chairman of the Collections and Exhibits Committee. Brian first argued to preserve and display advertisements and ephemera as a significant source for historical understanding and audience recollection.

[1]Ken Olsen, Gwen Bell, and Len Shustek are the story's heroes. Gardner Hendrie served in many ways, including initiating the oral histories process and collection. Bill Gates has been a 25 year supporter starting in Marlboro through funding *R|Evolution*. I'm afraid to name the many friends that were pillars of support for fear of omission. You know who you are. I thank the hundreds of members whom I don't know and who support and serve the institution; you amaze me with your dedication.

After 15 years, The Computer Museum in New England owned half of a building, as well as its critical collection of artifacts and pioneer stories. After another 15 years, the Computer History Museum in Silicon Valley has assets of over $70 million that includes an endowment, two wholly owned permanent buildings, and a major new exhibition featuring 3,200 objects, photographs and videos selected from its collection numbering over 75,000 items.

This accelerating progress is reflective of the maturity and scale of the industry, sensitivity to geographic locations, and most importantly, motivating contributing individuals[2] . The progress is also a reflection of a museum's basic tenet —"learn from its past[3]!"

This article is about the first stages of the museum's evolution to become the Computer History Museum. It is no doubt a story similar to other world-class museums. It takes time, if for no other reason than the need to accumulate the critical "Mona Lisas" that make visits compelling and support worthwhile.

Timeline: A 35 year Quest for Overnight Success

"Chance Favors the Prepared Mind" – Pasteur

The museum's six evolutionary stages of growth were accomplished by having the right, or "lucky," conditions for the inter-stage transitions over its 35+ year history, each characterized by a new location:

I. Concept and seed: Collectors and Preservers (distant past-1975)
II. Alpha: The Museum-in-a-Closet Project, Digital Equipment Corporation (1975)
III. Beta: The Digital Computer Museum, Digital Equipment Corporation (1979-1984)
IV. Going Public I: The Computer Museum, Boston (1984-1999)
V. Acquisition and Spinout: Boston Museum of Science July 1999; and
The Computer Museum History Center, Moffett Field, CA (1995-2000)
VI. Going Public II: The Computer History Museum, Mountain View, CA (2000- 2011)

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[2] My own view is that support decreases with distance from the creation of the objects: (1) founding creators from engineering, marketing, sales, etc.; (2) academic computing researchers including historians; (3) bankers aka VCs, PR, accounting, legal, etc.; (4) users; (5) local governments who benefit; and (6) communities and museum goers.

[3] CHM has learned from nearly every aspect of TCM, especially conservative fiscal management. Learning is through the continuity of long term board membership that include the heuristics for wide-scale public support.

I. Concept and seed: Collectors and Preservers

My own quest for a historical collection began in 1968 when Allen Newell and I wrote *Computer Structures* (Bell & Newell, 1971), which established a Linnaean-type functional taxonomy called PMS for the important information processing components[4] and more importantly the list and framework of critical artifacts to collect! Concurrently, Digital Equipment Corporation President Ken Olsen and Bob Everett, his former boss at MIT who led the Whirlwind computer project and was the President of MITRE, were pursuing the preservation of Whirlwind (which had the first core memory[5]) and the Lincoln Laboratory TX-0 (an early transistorized computer).

II. Alpha: A Computer Museum Exhibit in a Closet

In 1975 the so-called "Museum Project" opened an exhibit showing logic and memory elements from different generations and companies, with a booklet and my "talking" 35 mm slide presentation, that was housed in a converted coat closet in the lobby of Digital's ML-12 building in Maynard Massachusetts.

Having taken these baby steps to collect, explain, and exhibit computing, our expectations rose to the point that we thought we could actually create a first-rate public museum of computing. As an occasional visitor to Washington D.C., I concluded that such a museum was then outside the Smithsonian's charter. It was unlikely to mount the effort until it was too late, and the "Mona Lisas" would be gone. At that time they treated computing as a part of mathematics, whose curator was on a long sabbatical. By contrast, I was inspired by the Deutsches Museum, Munich (founded 1903) and the Science Museum, London[6] (established in 1857) where artifacts included many "first" machines, and the original plans of legendary computer pioneer Charles Babbage.

Friends at IBM supported our efforts to build a museum, although they were skeptical of our dream of creating an Information Museum in Washington similar to the Air and Space Museum. IBM appreciated

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[4] The PMS taxonomy is based on analyzing computer systems in terms of their Processors, Memories, and Switches and classifies computer components and information processing systems according to their function. This was described in the 1982 Digital Computer Museum Report TCM. (1980-1998).

[5] Ken was the project engineer for MTC, the MIT Memory Test Computer, which was used to test the first core memory of 1,024 16-bit words.

[6] At the opening in Boston, a viewer claimed it was the first US technology museum up to European standards. The relationship with the Science Museum began with a 1979 PDP-8 gift. We hired its curator, Dr. Oliver Strimpel in 1984 to help curate and build the museum. Oliver remained active, including being its Director, until 1998.

history. In 1971 they created a beautiful Eames-designed History Wall in the IBM World Trade building[7]. They introduced us to Roberto Guatelli, the model maker who had constructed the replicas of calculators and Hollerith's machines for that exhibit. We visited their climate-controlled artifact storage warehouse in Elmsford, New York that housed their pre-computer collection, which included one of the few priceless Pascaline calculators outside of France, Hollerith's first card data processing systems, and many classic IBM computers.

There were two important outcomes of this period. First, we found interest and support for a public museum from academicians such as Prof. I Bernard Cohen of Harvard and Prof. Brian Randell of the University of Newcastle, and from companies, some of which also donated key artifacts. Second, we realized there was no one else with the energy, vision, and commitment to take on the challenge. We were determined to create a public museum to preserve computing history.

III. Beta: The Digital Computer Museum at Marlboro Massachusetts:

In 1978, Gwen Bell joined the effort as a full time volunteer director to create a public museum in the Vincent Kling-designed, Madison Avenue-style, 6,000 square feet MR-2 Tower Building lobby in Marlboro, Massachusetts . The spacious lobby was ideal for exhibits, but little else! I adopted the affected title "Keeper" from the Science Museum, but I soon dropped it because nobody in the US knew what it meant. The nascent museum had access to Digital's departments for Advertising and PR, Finance, Legal, and especially the Industrial Design department that was part of the engineering organization I headed. The museum's budget for operations and exhibits was \$100K, \$190K, \$220K, and \$295K for the fiscal years from 1980 to 1983[8]. Staff, with interns history of technology programs, peaked at 8.

The Marlboro Lectures

On September 24, 1979, computer pioneer Maurice Wilkes opened The Digital Computer Museum (TDCM) with a talk on the programming of the Cambridge University EDSAC. His was the first of 15 talks by the innovators who had created the pioneering computers (see Table 1). Many of the talks were videotaped and all were publicized with a commemorative poster—a convention that has remained unchanged for over 30 years!

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[7]Described in *Computer Perspectives* (Eames, 1973, updated 1990).
[8] CPI 1984:2011 = 1:2.6

Table 1. Pioneers and Pioneer Computer Lectures at Marlboro

Maurice Wilkes: The Design and Use of EDSAC; Sept. 24th, 1979
George Stibitz The Development, Design and Use of the Bell Labs Relay Calculators; May 8th, 1980
Jay Forrester: The Design Environment and Innovations of Project Whirlwind; June 2nd, 1980
John Vincent Atanasoff: The Forces the Led to the Design of the Atanasoff-Berry Electronic Computer; November 11th, 1980
Konrad Zuse: Designing and Developing the Z1-Z4; March 4th, 1981
James Wilkinson: The Design and Use of the Pilot Ace; April 14th, 1981
John Brainerd: Development of the ENIAC Project; June 25th, 1981
David Edwards: The Evolution of the Early Manchester Machines; September 9th, 1981
Tommy H. Flowers: Design and Use of Colossus; October 15th, 1981
Arthur Burks: The Origin of the Stored Program; February 18th, 1982
Harry Huskey: From Pilot Ace to G-15; November 18th; 1982
Grace Hopper: The Harvard Mark I; April 14th, 1983
Donald Davies: Early History of Cipher Machines; April 24th, 1983
Robert V.D. Campbell on the Harvard Mark I-IV; October 23rd, 1983
J. Presper Eckert: ENIAC's 40th Birthday; February 13th, 1986 (at Boston)

There were a total of 45 lectures at Marlboro, including talks by Gene Amdahl about his WISC computer, Robert O. Evans on the IBM System\360, and Wes Clark and Charlie Molnar on LINC as the first personal computer. Maurice Wilkes wrote a play for the museum, "Pray Mr. Babbage," which was performed on December 10, 1982.

The relationship with John Vincent Atanasoff was an interesting outcome of his November 11, 1980 lecture on "The Forces the Led to the Design of the Atanasoff-Berry Electronic Computer" (Atanasoff, 1980). Atanasoff was a significant contributor to the invention of the computer by his first use of electronics, direct binary arithmetic, and methods of storing information in a recirculating capacitor memory. But his more significant contribution was to help invalidate the ENIAC patent, which placed the recipe for stored program computers in the public domain. His videotaped lecture is one of the most interesting stories in the archives, demonstrating the ability and necessity of video to capture critical history by providing insight into personalities. Atanasoff and I enjoyed a long friendship, and I encouraged him to write his story for the *IEEE Annals of* the History of Computing (Atanasoff, 1984). This may have led to an article and a book by Alice and Arthur Burks, and to the reconstruction of the ABC (Atanasoff-Berry Computer), directed by John Gustafson at the Dept. of Energy's Ames Laboratory. The reconstructed ABC is currently on long-term loan from Iowa State University and is part of the museum's R|Evolution exhibit. I consider the ABC reconstruction, one of the Mona Lisas.

The Collection and the Exhibits

In the beginning, almost everything in the collection was exhibited. The opening exhibits, with about 225 artifacts included: Whirlwind and the first core memory, TX-0, Calculators, Office of the Past, three cases each of Logic and Memory devices, Analog Computation, several DEC computers including an operational computer room being used by Digital, and Harold Cohen's Aaron[9] Paint System for generating computer art. Over a hundred pre-computing artifacts came from the Bell personal collection, which we began in 1975 with an early "Millionaire" calculator because we anticipated having a computer museum and the need for such objects. Objects ranged from a WWII Enigma cipher machine to a set of Napier's Bones[10] from about 1700. The layout of the exhibits is shown in Figure 1.

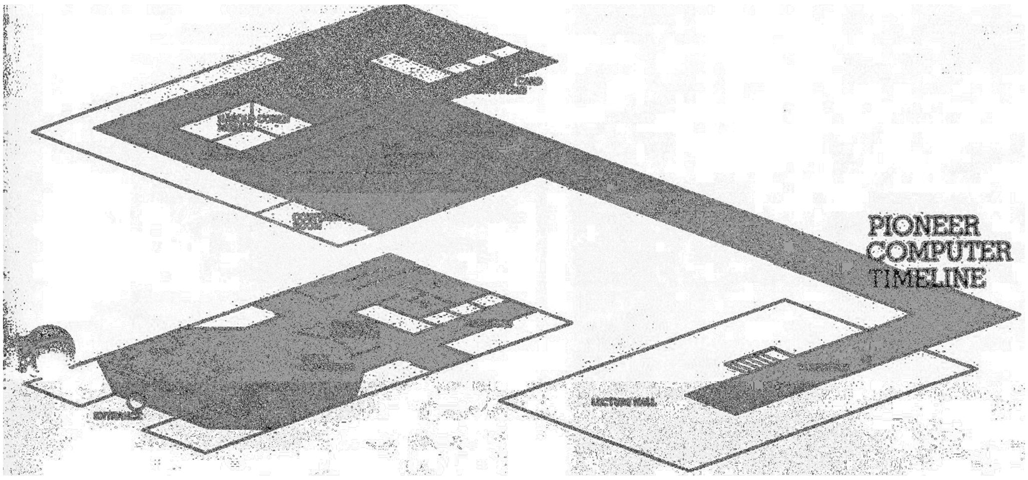

Figure 1. Layout of the Digital Computer Museum, Marlboro, MA at its 1979 opening from The Museum Report. The Lecture Hall was shared with Digital, who used it as their cafeteria. The museum was tucked into nooks, crannies, and all the otherwise unusable spaces.

The exhibits (documented in the television show, Computer Chronicles in 1983) were created using the centuries-old, well lit, artifact, label, photo format—unchanged in any way through 2011! The Marlboro exhibits also included several videos, a PDP-1 running Spacewar!, a PDP-11 for running Lunar-Lander, the Lincoln Laboratory TX-0l and a local VAX computer terminal to provide a guide to the exhibits. DEC's Industrial Designers used modular display cases and components that enabled the museum to become operational within its first year on a small budget. Unlike most subsequent exhibits, several of the early

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[9] A gift to the museum. In the 1970s I had provided Harold with a genuine PDP-11, after his PDP-11 "knock-off" computer had fallen from a truck, just prior to a European art gallery exhibition.

[10] The collection contained about 400 pre-computing artifacts and 500 books. See (Bell, 2011)

machines were were actually working, and visitors could interact with them. A small focus group of 12-year olds reviewed the exhibits prior to the opening!

Thomas Hoving's book "King of Confessors" (Hoving, 1981) describes an art museum director's search for rare and exotic artifacts. As we acquired artifacts and lusted over others on our acquisition list, we began to identify with museum directors' feelings about their collections. One of the first and most prized artifacts came from friends at Lawrence Livermore National Laboratory: the decommissioned CDC 6600 Serial # 1. TI's ASC followed, and the growing supercomputer collection soon attracted one of the few IBM Stretch machines. We began to understand that another important value of collecting "key artifacts" is that they attract other artifacts. No one likes to be excluded from immortality! The collection is the result of a directed, proactive effort—not a reactive one. Left open-loop, it is easy to miss new classes while passively accumulating a massive collection received from donors that just consumes warehouse space. A selective and proactive policy was easy to support when the museum was small. With a larger community, almost every artifact is a treasure—at least to someone, but usually not to computing or its history.

The museum's entire collection is listed in the TCM 1983 Summer Report according to the PMS classification. It included:

D/Data-operators i.e. calculators and analog calculating devices: abaci, slide rules, printed tables, sectors and other navigational instruments, the Lehmer Number Sieves, a Hollerith system replica, Napier's Bones, a Pascaline replica, Danny Hillis's Tinker Toy Computer;

D/Data-operation components: data-operation components: arithmetic units, logic circuitry, a valve (vacuum tube) from Manchester Mark I;

T/Transducers: telegraphy equipment, typewriters (subsequently discontinued), light pen, plotters;

M/Memories: Atanasoff capacitor store drum, core memories, delay lines, drums, handbooks, player piano disk, tapes, Williams tube.

C/Computers : Brigham Young University's video of the Stretch in operation, Bendix G-15, Burroughs ILLIAC IV (supercomputer), CDC 160 and 6600, Data General Nova, DEC PDP-1,5,7, 8, 11 (3 models), and 12, Fairchild Symbol that used the first dual in-line integrated circuit, Honeywell ARPA IMP, IBM 1130, 1620, 7030 (Stretch), and 360/195 console, Librascope LGP-30, Lincoln Laboratory LINC and TX-0, MITS Altair, MIT Whirlwind, NASA Apollo Guidance Computer, Philco 212, Raytheon Polaris Guidance Computer, Remington Rand Solid State 80, Siemens 2002, Sperry Univac NTDS (designed by Seymour Cray), Texas Instrument Advanced Scientific Computer, Viatron System 21, and Xerox Alto. Working computers included the restored TX-0 and Marlboro's VAX computer installation.

Other artifacts that were acquired before the move to Boston include: a Kurzweil Reading Machine for the blind, a Norden Bombsight, SRI's Shakey Robot, parts of a SAGE computer installation from a field trip to North Bay, Canada, prior to the acquisition, and a wonderful calculator and computer collection from the University of Illinois.

Visitors from DEC, Data General, and other New England companies in the Greater Boston area encircled by Routes 128 and 495 came to see the exhibits, attend the lectures, and offer advice. A museum logo, the 3-wire, co-incident core memory plane pattern, was created and served until 1995 when it was replaced as part of a comprehensive rebranding effort with a globe of 1s and 0s. Books[11], memorabilia, postcards, 35 mm. slides for historians, and posters plus ties, belts, scarves, etc. were sold in the "store."

The Computer Museum sponsored a two-day symposium in May 1983 at Marlboro on collecting and archiving. Attendees included historians Martin Campbell-Kelly, Ithel de Sola Pool, Jean Sammet, and Mike Williams as described in the Fall 1983 Report. Jean Sammet and I emphasized the need for taxonomic structures in collecting and there was total agreement for the need to preserve all films, especially the commercial ones showing operational system, even though they lacked academic reviews. I commented: "Let's only deal with the producer/storer problem, not the consumer problem (i.e. control of their purpose as the degree of authenticity). The Los Alamos tapes and the Museum lecture tapes were a valuable addition to the collections; in the first case the people were in a group and defending their turf and in the second they starred on their own. This basic "star" format is a mainstay with anniversary celebrations where everyone is brought together to tell their stories. Historian Mike Williams of the University of Calgary said, "Looking at a cannibalized piece of the ENIAC, like the one at the museum, doesn't do much for me. Why not just videotape everything and throw the junk out?" Twenty years later, when the web was established, I made a similar unsuccessful proposal as a Computer History Museum Trustee — that CHM should exist as a cyber-only museum with no exhibits other than a "visible storage" area. Having the *R|Evolution exhibit* on line will establish CHM as an important resource of historical information to complement Wikipedia's unparalleled encyclopedic content. By 2015 I would hope to see at least a factor of 10 difference between visitor time spent in the physical as compared to the cyber exhibits. Unfortunately, to do this will require a commitment to making the timeline somewhat complete as opposed to an exhibit of interesting mostly sculptural artifacts.

[11] Digital Press published two history books: Redmond and Smith, *Whirlwind*, and Sterns *From ENIAC to UNIVAC.*

The Founding Principles: Then and Now

The inaugural 1982 Digital Computer Museum Report claimed that “It is the world's only institution dedicated to the industry-wide preservation of information processing devices and documentation. It interprets computer history through exhibits, publications, videotapes, lectures, educational programs, excursions, and special events.” The report described the museum’s five principles, which *have remained essentially unchanged for 30 years*[12]:

1. Historical preservation. “To that end, the P,M,S notation forms the basis of the taxonomy determining the extent of the kingdom of computing and providing guidelines for exhibits.” *This provides a means of classifying* ***all*** *of computing: Class (i.e. P,M,S, K, T, L…C), order, family, genus, and species.*
   "You must feel like the Director of the Museum of Natural History when he started to collect bones." Jan Adkins, National Geographic
2. A lecture series for the computing pioneers and contributors to record their stories. “Thus, we are giving the podium to people who can give first-hand biographies of machines, programs and languages they have known.”
   "There is no history, only biography." Andy Knowles
3. “The focal point of the Museum is the machines themselves.” We agreed with Frank Oppenheimer who created the Exploratorium in San Francisco: "Well-engineered machines speak eloquently of their own elegance. Museum designers can't equal them."
4. A main “audience of computer scientists, programmers, history buffs, and those with a curiosity about computer evolution”
   "Hey, this Museum is for us big kids." George Michael, Lawrence Livermore Laboratories
5. “Broad-based involvement by maintaining a working relationship between the enthusiastic volunteers, donors of artifacts, patrons, students, scholars and a staff that can keep stirring the soup.”
   “The Museum does not have to convince the computer community to support the museum because its artists are worthy; they are the artists." Harold Cohen Creator of the Museum's murals

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[12] In 1993 TCM’s scope was explicitly extended to include a significant public educational function, which I thought potentially diminished its collection function. This change to “address a new and wider market” may have contributed to the decline in Boston that needed to focus on visitor attendance. However, the need for broad local support was necessary as the center of gravity of computing moved West. The extended charter did allow the museum to survive longer until its lucky move to Silicon Valley. Oliver Strempel believes “It was clear that operating expenses of the Museum Wharf site needed many strands, including earned revenue, which collections do not raise in significant amounts. Local support is always a backbone for any institution, even one with an international mission and reputation, and for that one needs to reach out to multiple audiences. Indeed, there would have been no reason to move into the Museum Wharf location if there had not been an education component. Much more cost effective would have been a Route 128/495 site.”

The interaction of the parts was given in The Computer Museum Report, Summer 1983 (see Figure 2).

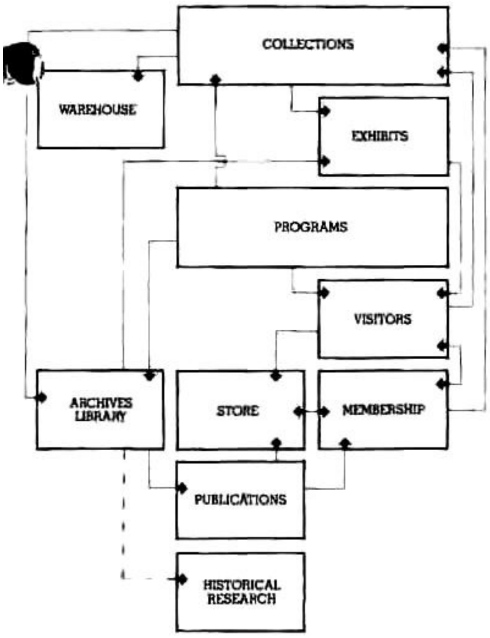

Figure 2 from The Computer Museum Report shows the growth from collections, to exhibits and programs that attract visitors, to access for research, to publications. Note the absence of a public education component.

Preparing to Go Public: The First Board

In late 1982 the museum became a public non-profit corporation called "The Computer Museum." The 18 member board consisted of six people from DEC and: Charlie Bachman, inventor of the Integrated Data Store, one of the first databases; Harvey Cragon, responsible for the TI Advanced Scientific Computer; Bob Everett, CEO of MITRE Corp.; Les Hogan, CEO, Fairchild; John Lacey, CDC; Pat McGovern, founder, ComputerWorld; George Michael, Livermore Computer Scientist; Bob Noyce, the inventor of the IC and Intel founder; computer scientist and historian Brian Randell of the University of Newcastle; Mike Spock, Founder and Director of the Boston Children's Museum; Erwin Tomash of the Babbage Institute; and Massachusetts Senator Paul Tsongas. Some IBMers, including Erich Bloch eventually became board members. It was Erich who convinced me that while The Digital Computer Museum name was clever, it might inhibit support from other companies, so we dropped "Digital." (One of the museum's interns suggested instead that Digital Equipment Corporation should change its name—a suggestion that Ken Olsen vetoed.)

During this period the notion of "Computer Generations" crystallized, and I extended it backward in time to include Four Pre-Computer generations. A poster was created *and sold* to describe events in the timelines (DCM, 1980): PC 4, manual 1600-1800; PC 3, mechanical 1800-1890; PC 2, electro-mechanical 1890-1830; and PC 1, electronic 1930-1945. These timelines were an essential guide for collecting. The Computer Generations I used then were given in a 1975 "Closet Museum" brochure: vacuum tubes, transistors, integrated circuits, and large-scale integrated circuits. My "Theory of Computer Generations" about the birth and death of computer classes (G. Bell, 2008) was stimulated by these attempts to understand how new kinds of computers come into existence and evolve to form industries based on hardware technology and the problems they solve. A new generation that occurs every 10 years also consists of a new software platform, networks, interfaces, applications and markets, resulting in the creation of an industry. Examples include personal computers, the web, smart phones, and tablets for reading.

The experience in Marlboro taught us about the collection process[13], how to preserve and exhibit artifacts from circuits to supercomputers[14], the importance of capturing the progress of technology through first-person lectures, how to operate as a public museum with a board, and the necessity of quarterly.

As the Marlboro facility started to outgrow its space, it became clear that the museum needed to move to a more public location to attract a wider, urban audience. Concurrently, Mike Spock announced that the Transportation Museum that shared a building with The Boston Children's Museum was closing. Like the two previous museum locations, moving the museum to Boston was another serendipitous event (see Figure 3).

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[13] The collection policy was proactive: know, seek and obtain the "first", mainstream, last, and interesting failures in each class. Collecting can also be a matter of luck. As the museum became better known, donors wishing to clear out a basement or garage could find it more easily.

[14] Unfortunately, the strong classification was dropped when it came to CHM: Computers, Memory/Storage, Processing, I/O, Transducers, Links, Switching, Networks, and especially Control (software) are not used. Thus a strong notion of a Linnaean-type of classification is not present at CHM and items usually revert to either a generic name e.g., "cable" or their industry trade name e.g., Ethernet!

Figure 3. Photograph of The Computer Museum, Boston at Museum Wharf c1983. The museum occupied the two top floors, a first floor entry, store, and the large elevator entryway visible at left.

For a technology museum, artifacts and archived stories are its balance sheet, and public support resulting from the mission and attendance make up the profit and loss. The experience at Marlboro focused on creating a sound Balance Sheet, and DEC supplied most of the seed capital and nearly all of the operating funds for the P&L! The museum achieved non-profit 501(c)(3) status, providing tax-deductibility for financial support, artifact donations, and memberships.

IV. Going Public I: The Computer Museum in Boston

On May 11, 1984 The Computer Museum (TCM) a preview opening for founding members took place at Boston's Museum Wharf with Bob Noyce's talk on "The Origin of the Integrated Circuit" (Noyce, 1984). The public opening occurred on November 13, 1984. Exhibits included a logic and memory timeline, Whirlwind, a 30' section of the SAGE Computer, its 64K word core memory and Air Defense Consoles, an IBM 1401 Computer Room from about 1965, Univac I, Seymour Cray's Computers, and a Graphics Gallery entitled "The Computer and the Image." The latter included the original, canonical "teapot" that served as a benchmark for graphics rendering. A layout of the exhibit is shown in Figure 4.

The museum's budgets in Boston for fiscal years 1983 and 1984 were $410K and $435K, respectively. The initial staff was 18, including the 8 that worked on exhibits. Attendance reached 135,000 annually, driven by the timeliness and relevance of major exhibits including: The Early Personal Computer

Collection Contest[15] (1986), Smart Machines (1987), Pocket Calculators (1987), The Walk-Through Computer (1990, 1995), Milestones of Computing (1990), The Networked Planet (1994), Kid's Software (1996), and The Virtual FishTank (1998). Exhibits like The Walkthrough Computer served as a stage for video creation (How Computers Work, 1990). In 1997, TCM and the ACM, which was celebrating its 50th anniversary, produced two 50-minute videos utilizing the museum's artifacts and archives. They are now part of CHM's YouTube channel (TCM, 1997).

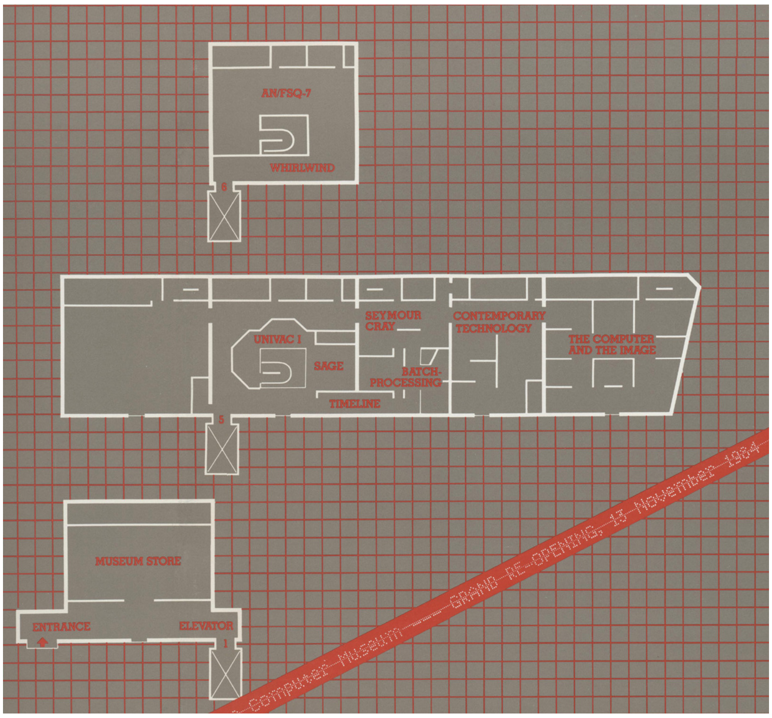

Figure 4. Layout of The Computer Museum, Boston at the opening in 1984. Exhibits occupied about utilizing 11,000 sq. ft. of the total 55,000 sq. ft. area on the two top floors on Museum Wharf.

The museum operated for 15 years, until July 1999. During this time, many key artifacts were collected from the supercomputer, 10 mainframe, 100 minicomputer and hundreds of personal computer companies and their users, who were often anxious to find a good home for their obsolete computers rather than consigning them to trash. One of the most valuable artifacts and a "Mona Lisa" came from the Los Angeles Museum of Science in a serendipitous fashion. Willis Ware, a principal at the RAND Corporation in Santa Monica CA, discovered that their beloved JOHNNIAC Computer, one of the few inspired by von Neumann at the Institute for Advanced Study, was being discarded by the museum and

[15] In 1986 ComputerWorld sponsored a contest to acquire early PCs that resulted in 500 artifacts marking the beginning of the PC generation.

was awaiting a trip to the dump. Willis called Gwen, and TCM acquired a computer which is now a national treasure. That museum had violated one of the most important tenets of institutional support: never get caught by the donor discarding his precious artifact! De-accession is a tricky business that must be done carefully.

Other activities evolved, including the use of the collection for prior art research in patent litigation. An operational PDP-1 displaying one of the first computer games, Spacewar!, is still used for this purpose. In 1988 Gwen created The East Coast-West Coast competitive Computer Bowl, that ran through 1995 and garnered wide support. A gallery and book, Wizards and their Wonders featuring prominent people of computing was also used to recognize and gain support (Morgan and Bachrach, 1997).

In 1993 the mission expanded to include education, resulting in the creation of The Computer Clubhouse for teens in collaboration with Mitch Resnick of the MIT Media Lab. From 1990-95, a significant part of the museum's funding was directed to major new exhibitions. Most of the financial support for new exhibits came from Silicon Valley firms, reflecting the industry's new central location. Overhead from exhibit creation was used to defray operating costs.

What had started out as a museum focused on history and collecting had now expanded to become a public computer education institution. This philosophy posited the museum as a "third wave" focused on education and historical collection[16]. However, given the public focus on education, the need for a "back room" collection of artifacts diminished, along with the interest and understanding of the importance of collecting and preserving.

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[16] Oliver Strempel noted: "The exhibits were effective manifestations of this philosophy. For example Smart Machines included The Robot Theater, a stage packed full of key robot artifacts, including Shakey, The Stanford Arm, Unimate I, an early industrial arm from Raj Reddy's lab at CMU, and the 1984 Mars Rover prototype from JPL. The functioning and purpose of these artifacts was explained in a video, and synchronized lighting and robot movements helped pinpoint the robot being featured in the video. Other exhibits in the gallery explained concepts of AI and robotics with interactive exhibits. A similar approach was adopted in The Computer and the Image with early computer graphics artifacts and ground-breaking animation from BYU, NYIT, Lucasfilm, and Lawrence Livermore Labs. The Milestones of a Revolution exhibit placed representative artifacts of each era in a contemporary setting, and explained the innovations they embodied in text, graphics, and interactive demonstrations."

By 1998, most of the exhibit support was coming from hardware and software companies outside of the Boston area and artifact collecting in Boston was nil. Gwen outlined the dilemma that even though computer manufacturing had left New England, there was significant support from the city, state, and Boston companies. In a late 1997 memo to the executive committee, Gwen wrote:

> "From almost the beginning, The Computer Museum has been marginal in its location on Museum Wharf. The site never lived up to the "industry standard" of refinement or pizzazz. Efforts to provide a "visionary future" had no serious backers. In 1987, the mission was re-worked to focus on education; collections and history took a back seat. From 1990-95, the Museum was in reasonable shape via a series of successful industry-funded computer-focused exhibitions. Spending little money on the collections/history allowed the funds from those supporters to go to the public facility. Today, with no major computer-focused exhibit that is well funded, and without the marginal extra resources brought from those who support the history component, the Boston facility is struggling from month to month, with no respite in sight."

Interest in: where did computers come from, how do they work, and what do they do had been satisfied. In essence, market demand was inadequate to support the high cost of exhibit development to show the future or build extremely interactive exhibits like the museum's 1998 Virtual FishTank.

A Silicon Valley Division Or What?

In late 1994, Len Shustek called me.

"I want to start a computer museum in Silicon Valley like the one in Boston. How do you start a computer museum?" he asked.

I responded: "I have a deal for you."

We spoke for several hours and outlined a plan that would bifurcate TCM by establishing a new Silicon Valley division called "The Computer Museum History Center" to house the valuable collection, and focus on extending it by collecting semiconductors, storage devices, and personal computers from the artifact-rich Silicon Valley. TCM in Boston could get rid of its collecting charter and the dusty "back room" of artifacts, which Len and Silicon Valley were eager to adopt. TCM could concentrate on exhibits, public access and education. Furthermore, since by now the artifacts were now largely being created in Silicon Valley, collecting them there was both natural and essential. Having a significant number of board members from Silicon Valley certainly increased the odds of the plan being accepted when the question was eventually called. Furthermore, a strong and active Silicon Valley board was essential to implement a new venture in the valley.

Future history was being created in real time at an increasing rate, and the creators and artifacts had to be captured near the source. Technology had moved west, and the museum had to follow it or risk having its collection become irrelevant and, paradoxically, obsolete!

Va. Takeover: The Boston Museum of Science Acquires The Computer Museum

In mid-1999 TCM in Boston was dissolved. The assets relating to science and technology education were acquired by The Boston Museum of Science, since both museums were serving the same science and technology education audience. They were not equals: TCM and the Museum of Science had attendances of 135,000 and 1.9 million annual visitors respectively, operating budgets of 3.4 and 36.5 million dollars, and staffs of 25 and 650 persons. But with collecting out of the way and in California, the two east-coast museum charters were identical, and TCM could just beef up the Science Museum's computer exhibits. Besides, now nearly everyone had a computer, and it was becoming increasingly difficult and very expensive to exhibit constantly evolving new technology that consumers couldn't buy from computer stores.

In any event, TCM could not have continued independently. Significant exhibit and overhead support had come from Silicon Valley, and the new History Center there reduced the eastward flow of funds. The challenge for TCM in Boston would have been to operate independently with just local, government, and company support, in the face of a diminishing computer industry led by Digital's decline. The Boston's museum's Board simply lacked the willingness and ability to continue to fund a computer museum.

When TCM closed it delivered a dowry to The Museum of Science of half the cash from the sale of the Museum Wharf building, a loan of artifacts for an exhibit, the Computer Clubhouse network, and TCM brand that MOS subsequently abandoned. Basically, the TCM board was just weary of fundraising in the competitive museum-rich Boston environment, and the acquisition gave the board a graceful exit. Many of TCM's board and overseers who were not interested in the computer history mission were able to become part of MOS, a more prestigious Boston institution with a larger personal network "net worth".

By March 2009, TCM had been completely assimilated and its history mostly erased. A watered down version of The Virtual FishTank remained, as well as the flagship Computer Clubhouse, the headquarters of the Computer Clubhouse Network. For example, the Museum of Science states on its web site and in press releases:

"Founded in 1993 by the Museum of Science, Boston in collaboration with the MIT Media Lab, the Computer Clubhouse[17] is a creative and safe out-of-school learning environment where young people from under-served communities work with adult mentors to explore their own ideas, build confidence, develop 21st century skills, and find pathways to success through the use of technology."

The cause of the takeover is identical to what we observed in our earliest interaction with the Smithsonian, which is what originally prompted the need for the creation of a computer museum:

> To a science or technology museum, computing is an exhibit.
>
> To a computer museum, everything in the world, besides computers, is a computer peripheral or there to be a part of computing.

Vb. Spinout: TCM History Center Forms in Silicon Valley

In 1995, Shustek proposed:

> *"establishing a world-class academically-oriented Computer History Center focused on technology and its evolutionary development; move TCM collection and expand it; build an artifact rich museum targeted at adults; allow limited, professional access of the entire collection as "visible storage," and a library, seminar series, research projects; and Web availability."(Shustek, 1995*)

The plan was simple: secure a donated site; build a 60,000 square foot dedicated facility; operate primarily from endowment by securing $15 million each for a building and endowment. *Realizing this vision would take 15+ years, and the numbers were bigger, but the result would be worth the wait!* The beauty of *collecting* museums of technology is that they don't need to operate on a schedule—they just have to "hang in", stay alive, and keep on collecting. The Balance Sheet of artifacts just increases over time with an active collecting program.

During 1996, TCM History Center was established, governed by TCMHC's West Coast Board of Overseers and operated by Gwen Bell, Len Shustek, Carol Welsh, Dag Spicer, Karen Mathews and a number of other volunteers. TCM's artifacts began to move to Silicon Valley along with a large stream of new "old" artifacts coming from local valley supporters. On December 2, 1997 five semi-trailers full of TCM's artifacts arrived at a Moffett Field warehouse where Len had convinced NASA to provide free space — our next lucky break. This represented most of the larger artifacts that would be featured in the "Visible Storage" exhibit, (see Figure 5) which was a way to convince supporters that a building was worthwhile and was going to be built. Another exhibit opened at Stanford's William H. Gates Computer

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[17] This clause of course is false. Unfortunately or perhaps even more generally, history is often written by the last institution or person standing and their public relations department.

Science Building in November 1997 to further stimulate support. The remaining artifacts arrived in 2000.

Figure 5. Panoramic photo of The Computer Museum's History Center Moffett Field Visible Storage area.

From the beginning, The Computer Museum History Center was required to be financially independent of TCM. Not only did it receive no money from the mother ship in Boston, it was required to pay a “tax” to TCM 25% of the funds it raised in Silicon Valley. But the staff was small, the enthusiasm high, and there were enough successful entrepreneurs who understood that the original collecting mission could not be allowed to die. A campaign to sign up hundreds of “Founding Members” was very successful.

When The Computer Museum History Center was established as a subsidiary, TCM had a 19 member Board of Trustees and 55 member Board of Overseers. Silicon Valley participants included Dave Anderson, Jeff Braun, Lacy Edwards, Peter Hirshberg, Terri Holbrooke, Chuck and Dave House, Christine Hughes, Carver Mead, Ike Nassi, Suhas Patil, Bernard Peuto, Grant Saviers, John Shoch, Len Shustek, Bill Spencer, and me.

In anticipation of TCM’s demise, TCMHC was incorporated as an independent California 501(c)3 non-profit organization on January 15, 1999, temporarily sharing the same trustees as TCM. By the end of the year TCM had been dissolved, and the November 12, 1999 TCMHC board meeting is described in the minutes as “the day of the History Center’s independence.”   Trustees not interested in the original history mission resigned, and the board was repopulated with 12 surviving and 7 new trustees: David Anderson, Gordon Bell, Andy Cunningham, Sam Fuller, Gardner Hendrie, Dave House, Peter Hirshberg, Christine Hughes, Steve Kirsch, Isaac Nassi, Suhas Patil, Bernard Peuto, John William Poduska, F. Grant Saviers, John Shoch, Len Shustek and Pierluigi Zappacosta. In February 2000, the museum’s name was changed to the Computer History Museum (CHM), because “TCM” was owned by the Museum of Science and was not available.

Fortunately, the first few years of TCMHC had coincided with the “Internet Bubble,” which allowed it to get commitments of over $50 million for the proposed building and the endowment. With its impressive display of “first” or “one and only” artifacts in the warehouse (arranged as a “Visible Storage” exhibit), an active collecting program, a lecture series, and a project to restore an IBM 1620 computer system, the board had a credible story to use for fundraising.

VI. Going Public II: The Computer History Museum

The museum originally intended to construct a new building on land leased from NASA at Moffett Field as part of a research park being developed. But it soon became apparent that NASA was moving with the speed typical of a federal bureaucracy, so in October 2002 the museum purchased what had been the 119,000 square foot main marketing building of Silicon Graphics Inc., for $25 million (see Figure 6).

Figure 6. Photo of the 119,000 sq. ft. Computer History Museum, 1401 Shoreline, Mountain, View, CA. CHM hosts a 25,000 sq. ft. Revolution timeline of computing history.

Unlike many investments, the museum had been able to “sell high” at the peak of the bubble by getting capital pledges, and “buy low” when the bubble burst making real estate available inexpensively. The move of key artifacts from Moffett Field was completed, and in May 2003 and the museum opened on a limited basis by offering a new “Visible Storage” exhibit, followed by an exhibit on Computer Chess and Artificial Intelligence in 2005. Staff and volunteers proceeded to restore computers, collect, and digitize items, in addition to being enthusiastic and knowledgeable docents.

Software was finally added to the list of classes collected, and we acquired key items, such as the history of FORTRAN including original source code. Paul McJones who hosts Dusty Decks for archiving software, noted:

"similar collections for LISP, ALGOL, and C++. Others have assembled extensive collections on, for example, the Multics and Unix operating systems, PDP-10 systems and applications, and many more. Two of the earliest relational database management systems, Berkeley Ingres and IBM System R, have been preserved but are not yet easily accessible. For the most part, these collections are aimed at a more scholarly audience; I hope they will serve as source materials for future exhibits for a wider audience."

The 1/10/11 opening of the R|Evolution exhibit (see Figure 7) at the Computer History Museum clearly accomplished the 1995 vision. Every parameter of the plan was realized, and done so by more than a factor of two—scope, building, and financial base. In 2011, CHM has over 35,000 physical objects, 5,000+ linear feet of pages, 15,000, photos, 5,500 videos including a number of Pioneer Lectures, 400+ oral history transcripts[18], and 20,000 software objects in a variety of formats. Sadly, with so many artifacts, an exhibit of 1 per cent of the artifacts described in 50-100 word sound bites is a sampling and thin veneer of computing history. The void, selectivity, and rigidity projected from an exhibit of sculptured items is apparent when viewed in what is an infinite cyberspace.

The "Mona Lisas"

Museum visitors often ask, "What is your Mona Lisa?" How can we answer that? What are the defining criteria? Is it the artifact's properties? Its place in history? What it inspired? About two dozen artifacts (shown in italics below) in the CHM's 2011 Revolution Exhibit strike me as possible Mona Lisas (MLs). All of the MLs except three, which are on loan, came as part of The Computer Museum's collection. The MLs validate the early 1970s rationale to collect and capture pioneer stories that were the bedrock of TCM.

My first ML is the Marlboro museum's 18th and 19th century artifacts such as *Napier's Bones*, printed tables with known errata, and the uncommon artifacts previously listed. Although I'm not a fan of replicas because they make no pretext of operating, I include Guatelli's replica of the *Hollerith Card System* used for the 1890 census since it represents the origin of IBM. His *Pascaline* c1647replica is important as the basis of mechanical, stepped wheel calculators that dominated mechanical calculation for two centuries. The *CDC 6600* was a computer that all engineers admire, and the *Enigma* fascinates everyone. Nathan Myhrvold's Science Museum operational reconstruction of the *Babbage Difference Engine No. 2,* on loan to us, is the most impressive artifact anywhere! (6 MLs)

[18] A program initiated by board member Gardner Hendrie that includes HD Video capture.

MIT's *Whirlwind with the first core memory* and interactive displays, the TX-0 with CRT and *light pen* (a mouse precursor), and subsequent *PDP-1 with Spacewar!* demonstrate the first 15 years of interactivity and the beginning of personal computing and the minicomputer industry. Wes Clark's *LINC (Laboratory Instrument Computer)* qualifies as the first personal computer and stimulated *Digital's PDP-8*, which in turn inspired the creation of 100 minicomputer companies. The museum has over 500 different PCs in its collection, including an *Apple I* that is interesting because of its scarcity; one recently sold for $240,000 to a collector. The 1981 *IBM PC*, like the System/360 before it, succeeded in establishing "the" set of standards that will live for decades . *Xerox PARC's Alto* was the basis of many innovations including user interface designs, word processing, paint systems, software fonts, and especially distributed computing using the *Ethernet* Local Area Network. (7 MLs)

At one point in the exhibit the visitor can view a *1,024 bit core memory plane* from the Whirlwind that dominated primary memory use for two decade and *IBM's RAMAC*, a 5 megabyte disk, the first of its kind. The storage alcove has many other devices that were successes, and many that were not. Unfortunately, the relational database along with many other critical software artifacts is not on display. (2 MLs)

TCM had acquired a few "Cray" computers. Now CHM has virtually every Cray model spanning 40 years, with pride of place going to the *Cray 1*. Of all the computers, Cray's machines most qualify as Mona Lisas based on their aesthetics. The CHM supercomputer exhibit is a David and Goliath Story: the Cray architecture, based on speed at any price, was replaced by clusters of "killer" micros beginning with Caltech's *Cosmic Cube in 1982* and then by subsequent Intel systems. *ENIAC, JOHNNIAC*, and the *UNIVAC* I are all firsts that qualify, along with an *IBM System/360*—the computer with the longest lifeline introduced in 1964. Atanasoff's 1941 *ABC Reconstruction* and Lee *Boysel's 1969 microprocessor* and their stories are unique as firsts, and as patent and myth busters. (7 MLs)

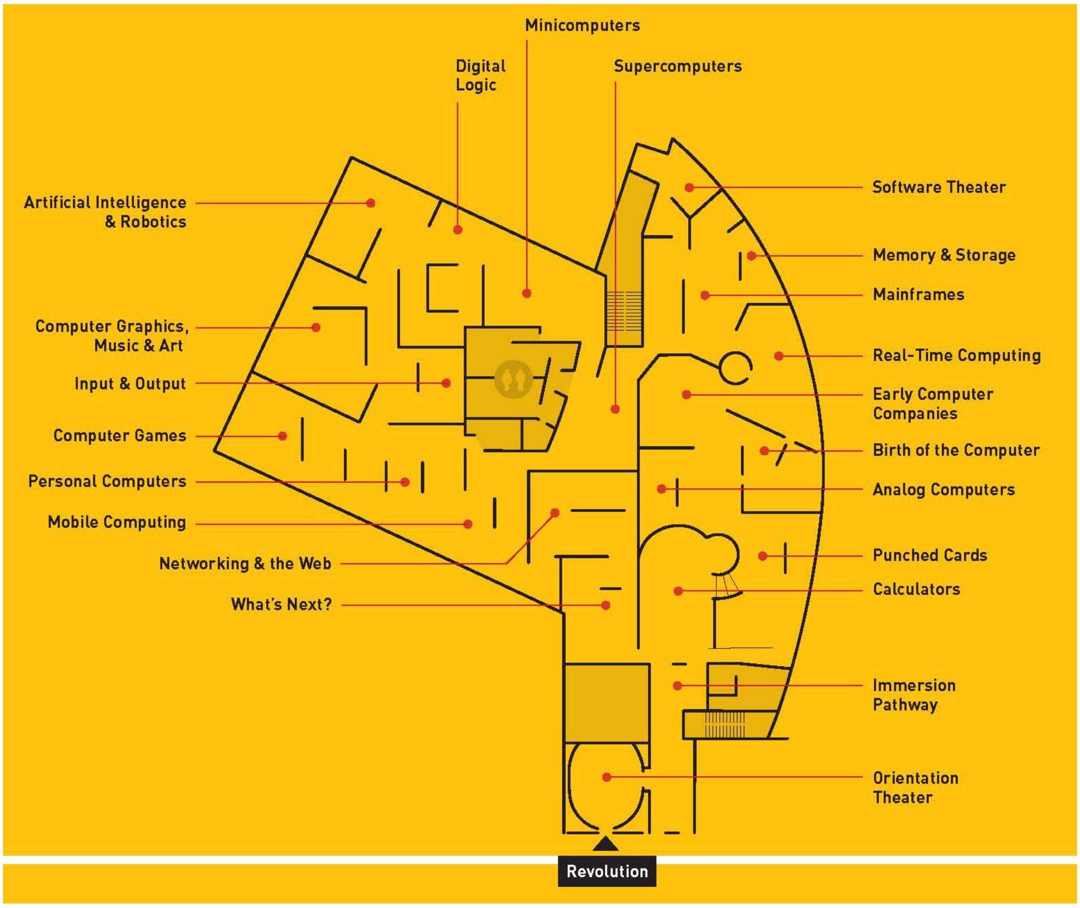

Figure 7 R|evolution: the first 2000 years opened on 10 January 2011. This 25,000 sq. ft. exhibit features 1,200 artifacts, 2,000 photographs, 750 graphic panels with 100,000 words, 5 hours of video, and incorporates 50 oral histories.

The *ARPA IMP* was the seminal computer used for packet switching in the ARPAnet -- the basis of what became the Internet and Worldwide Web (1 ML).

The AI and Robotics Gallery has an assortment of robots, and various computers that led to IBM's *Deep Blue*, which won the world chess championship along with the *Unimate I*, the first industrial robot, SRI's Shakey Mobile Robot, and *Edmund's Berkeley's c1950 Squee* robot to fetch tennis balls. (4 MLs)

Regrettably, I omit that hard to see, hard to describe, essential software from COBOL, FORTRAN, and LISP, various Operating Systems, Bill Gates' BASIC paper tape for the Altair, and on through Visicalc, and the Relational database.

All of these artifacts came as part of The Computer Museum spinout.

Summary

The public opening of the *R|Evolution Exhibit* at the Computer History marked a key achievement in the quest to create a world class, permanent, public institution to collect, exhibit, and understand the artifacts and personal stories of the information age—and to tell these stories to everyone interested. The purpose is permanent preservation, with comprehensive cyber and physical access to all artifacts, exhibits, interviews, lectures, machines, software, etc., as Len Shustek envisioned in 1995 (Shustek, 1995).

Each of the five lucky transitions were based on the fortuitous availability of space and capital to operate the museum at the next level [19]. The decline of computing in New England to supply the technology, causing the inability to sustain a high tech museum for museum goers was the final "lucky" bittersweet catalyst that allowed the museum to move to where the "current" action is, in order to focus on the history of the future! How CHM evolves in the next decades is TBD—stay connected.

Acknowledgements

Gwen Bell, Jim Gemmell, Vicki Rozycki. Dag Spicer, Oliver Strimpel, and Karen Tucker were all critical by fact checking, reviewing and editing this paper. Len's edits were adopted entirely as its latest reviewer.

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[19] At various times, a tired TCM board was on the verge of closing the institution because sustainability is so tiring to a board as it grows large, diverse, and less interested in, or committed to computing and its preservation when the "going gets tough". Technology museums that evolve to be based on having the latest "gadgets" to please an expectant public are especially difficult to operate over a long time frame because of technology half-life.

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Appendices, After-thoughts, and Overviews

The appendices are a collection of after-thoughts and overviews.

Appendix 1. On creating a survivable museum, for capturing the computing revolution.

"Just don't let it die."

These computing museums are like a high tech startup… people, people, people; people product plan; market, product, people.

People, market, product may have been the history. The TAM (total available market) in Boston for people interested in computing after much of the population has computers that were connected to the Internet, and if became just another interesting alternative "thing" to do on a rainy day.

Boards, Trustees, Overseers, Advisors

"Many hands make light work."

This is unclear. Does output vary with size or decline as more people are responsible?

Three Gs[(Glory, Give-Back, Greed) or (Give, Get, or Get-off)] have been mentioned at the motivating and ruling factors for board and advisory board members. My own belief is that in general, motivation varies inversely with distance to the artifacts and people.

People join boards for various reasons. Most all seem to join based on who's on the board independent of their belief about how they can contribute to an institution. The hierarchy:

1. Direct involvement in the creation: founders, engineers, marketing, sales, etc.;
2. Academicians expert historians
3. industries supporting the creation: bankers aka VCs, PR, Marcom, accounting, legal, head hunters;
4. Users;
5. Community, community leaders, and various people with no other place to go

Board Evolution

With the 1984 opening, Bill Poduska, the founder of Apollo Computer, became the Chairman of a board of 24 that included Erich Bloch, former head of manufacturing at IBM and Director of the National Science Foundation; Syd Fernbach, former director of Livermore National Laboratory; Mitch Kapor, Lotus founder; Koji Kobayashi, NEC Chairman; Arthur Molella, Smithsonian; IBM programming technologist, Jean Sammet; and An Wang, founder of Wang Computer. By 1986, the museum had 23 board members, 12 trustees, 500?? members, and 50?? corporate members.

Financial & Management

"Numbers are hard!" --Barbie

At the root is the financial structure and the ability to fund operations and rationalize its service to a community it serves. In Boston, the number of large gifts by individuals and corporations of over one hundred thousand dollars was very limited, with Digital as its main supporter. Companies and several individuals including Bill Gates, Mitch Kapor, and Russell Noftsker gave very large gifts or grants for the construction of the Walk-Though and AI Galleries.

Appendix 2. Artifact Classification: A "Linnaean-like" Structure is Essential. PMS needs to be it!

From the beginning TCM had the understanding of classifications and taxonomies as reported in the first reports. The big three dimensions were: its structure by functional types or PMS; the Computer Classes as they have continued to emerge since the 1960s; and the hardware technological eras that are in essence marked by logic and memory densities and communication links.

The structural rigidity of PMS was essential lost in the move to CHM. For example, two of the most significant dimensions, Transducers and Links were relegated to a renegade committee who couldn't deal with such details as a taxonomy except in the adoption of The Dublin Core[20]. Transducers became ambiguous I/O devices that lost both low and higher levels e.g. photonic devices and software concepts (e.g. User Interface). The museum chose the easy way out by simply adding generic names for links e.g. undersea telegraph or telephone cable, Ethernet, WiFi, Firewire, instead of using a two or three level classification based on links and link technology e.g. cable, fiber, sonic, optic, and radio and structure i.e. connecting computers or other information processing components, or components within a computer. However, in general, they chose to ignore the fact that links and link protocols e.g. undersea cable, Ethernet, GSM, don't exist thereby ruling out the significance of Shannon whose work is about how much information can be transferred on links of varying sizes and error rates. Thus, similarities and differences of how data is transmitted are completely lost.

A museum ultimately needs to impose a Linnaean structure on all the artifacts along the lines of Classes (PMS Component type), Orders, Genera (or Genus), and Specie and even the lower level varieties that would characterize various models.

[20] The Dublin Core provides about a dozen meta-data attributes for a document or object. The important ones, function, technology, generation require a taxonomic or ontological framework.

Finally, software is not classified in the same system as hardware, but is taken to be ethereal and different. Thus it doesn't exist, can't be traded off with a hardware component, or identified by function. While having a fine software structure is possible it flies against the ACM Taxonomy and keywords, plus the many alternative classifications that attempt to group stuff by kind.

Appendix 3. The Bell Book and Calculator aka Pre-Computer Collections

In 1975, Gwen Bell and I began a proactive collecting program by purchasing a 1903, Six digit, Millionaire calculator, rationalizing that a pre-computing collection would be useful and even necessary for eventual exhibits for a comprehensive museum. Furthermore, while it turned out to be a good personal investment, we could not rationalize buying artifacts for the museum because the museum had no money for investing. Our artifacts were purchased from antiquarian instrument dealers, flea markets, and dealers at London's Bermondsey and Portobello Rd. Markets. When the museum opened in Marlboro there were about 80 books, calculators, and navigational instruments.

By 1986 the Bell pre-computing collection contained about 400 artifacts and books. Artifacts included calculating and navigational instruments, a Boxwood Napier's Bones, a Jacquard loom model and silk weavings, two Enigmas, and slide rules. The artifacts and books from this collection were moved to the TCMCHC. This collection turned out to provide a rather complete base of early artifacts that few museums possessed. Early books included Napier's Rabdologiae and Logarithmorum, and Babbage's book on Manufacturing.

Appendix 4. Going Public: The Computer Museum, Boston (1984 -1999)

Gwen described the museum's state, at the opening on Museum Wharf, in The Computer Museum Report of Fall 1984:

> "In our countdown to opening the Museum, I am pleased to have the opportunity via the report to reflect on the evolution of the Museum. Five years ago, I was charged with the task of creating a "computer museum." The only models at that time were IBM's dismantled history wall done by Charles Eames in the sixties,. the small exhibit of historic machines at the Smithsonian, and the interactive and historic collections at the Science Museum in London. None of these could be collected and brought back. And I felt as though I had been told to "Go fetch a rock." Every time I brought an idea back, the feedback was quick: "That's not the rock," or "How did you ever get that-it's just great."
>
> Two and a half years ago on June 10, 1982. The Computer Museum opened its doors for the first time: we had 50 Founders, 200 members and 3,000 square feet of dedicated exhibit space. Our goals were to develop an international collection, create exciting exhibitions, sponsor educational programs, and attract a worldwide membership. On June 24, 1984 at the end of our Founding period, we will boast 504 individuals and corporate Founders. I am glad to extend special thanks to the individuals listed on the front cover and the corporations listed on the back cover helping to found the Museum.

The Second Opening

On Wednesday. November 14. 1984 at 11:00 a.m., the Museum will formally open its doors a second time to the public. This time we will have 16,000 square feet of exhibitions of both historic computers and state-of-the- art interactive displays: another 8,000 square feet of exhibit space and 4,000 square feet for library/study collections will be developed later. As we approach our opening we can be pleased that we have by for the largest exhibition area devoted to computing and information processing at any museum.

Let me give you a brief tour. Going around the comer, the visitor enters the SAGE computer room, Here the major components of the world's largest and longest lived computer simulate their installed environment.

The visitor can "start" the console and see its banks of lights cycle-up. Beside each component, such as the 30-foot-Iong accumulator, today's equivalent chip (or part of a chip) has been placed for comparison. This arrangement reinforces an awareness of decreasing size and power and increasing programming capabilities.

For the history buff. a year-by-year Timeline from 1950 to 1970 shows the fundamental inventions, the major computers, major software developments and benchmark applications.

The CW Communications "See It Then" theater shows films of operational computers starting in the 1920's and ending in the 1960's with the IBM Stretch. The films are complemented by a 1965 IBM 1401 computer room where the visitor can punch cards and an operating PDP-8, the classic (but now very slow) minicomputer.

The evolution of Seymour Cray's work illustrates a single hardware contributor and his philosophy. The story begins with the NTDS-17 that he built for the Navy at UNIVAC in Minneapolis, which Greg Mellen. who is still at Sperry Univac helped the Museum acquire: after that Cray built the Little Character, his first machine at CDC, presented by Control Data Corporation: then to the 6600, Serial Number 1, presented by Lawrence Livermore Laboratories; and finally to components of a Cray 1 presented by the Cray Corporation. We have two videotapes of Seymour Cray: one from Lawrence Livermore Laboratories and another given to us by Joe Clarke, a former employee of CDC who bought a two inch video tape player at a company sale and found on it a tape of Seymour Cray.

The next gallery focuses on chips and their place in the computer revolution and the process of manufacturing computers. The inside of the "black box" is revealed and an important hidden part of the process is illustrated.

This collection of personal computers goes back to the very first one, the 1962 LINC and extends to the latest models. The ring of live machines, each showing off an aspect of its special input/output. include DECTALK, a touch sensitive screen HP 150 and others.

The final gallery is devoted. to "the computer and the image." Here. the visitor will be able to explore image processing by computer such as evaluation of landsat data, and image creation by computer. such as computer- aided. design. Without much trouble, the visitor could spend two hours in this room experimenting and viewing.

The exhibits are only the tip of the iceberg of our collection of artifacts, working machines, software, documentation, photographs and films. The listing in this report represents one year's accumulation and the collection is rapidly growing.

Restoration Projects.

At Marlboro there was one restoration project—getting the TX-0 c1956 operational. Fortunately, John McKenzie who worked on and attended to it at MIT was able to get the machine operating, and on November 13, 1983 its alumni gathered to watch it run programs that we remembered and to tell stories about how we used it. The TX-0 was returned to the Lincoln Laboratory in Bedford, Mass where it resides and is on display.

The CHM had three very large restorations: IBM 1620, DEC PDP-10 and IBM 1401 complete with disks and tapes.

Appendix 5. On Collecting: When to Accept Artifacts or What to accept?

"We can meet the schedule, stay within budget, or deliver the spec. Pick two!" –Dave Cutler

The nice thing about a museum of modern technology is that the schedule can be indeterminate, as long as the artifacts or creators exist. There is no deadline, and the only constraint is you can't run out of money and die! History usually gets better with age as more is revealed and the risks are an artifact gets discarded or inventors die off before we can record or understand their contributions "in their own words." In the latter case, the history has to be acquired from secondary sources. By not chasing all the creators and contributors, the result is that history risks being solely created by the last ones standing. As more museums exist, then competition exists for the first and perhaps only. Staying within budget is another matter and for a public museum, budget determines the schedule and spec. During all of the phases and places of the museum budget has been the constraint. The Museum has generally chosen to limit the specs and hence maintain collections and provide quality exhibits to a limited audience. The result has been a slow, growing museum that has taken 35 year to be discovered as an "overnight success."

In retrospect, the museum was born at exactly the right time: it was young enough to aggressively collect the one-of or pioneer computers and the first-person story versions from the pioneers. Unlike other technological museums, computing evolved rapidly as Bell's Law describes with a completely new computer class being created every decade *and since 2005, every five years*. Thus the museum was able to be an active collector as artifacts are created including being able to capture breadboards and prototypes prior to them being declared salvage. The only risk is that history will somehow claim that a particular artifact or computer science discovery wasn't captured.

Regrets: We just didn't preserve the museum's history

Lectures—didn't videotape every one

The Computer Museum History is only partial. Detailed views of all the past exhibits do not exist.

Was it worth moving to Boston given that the real gain was the collection?

Enumerate what Boston contributed… trained, books, artifacts

Exhibits and Lecture Series

During the 15 years at the Boston site, a number of exhibits were created by getting a substantial amount of external funding from individuals. Mitch Kapor (Lotus Founder) and the Sloan Foundation gave major grants to fund a large scale walk-through computer. Russell Noftsker and his fellow Symbolics Founders funded the Smart Machines Gallery. In fact, the creation of exhibits and the associated collecting turned out to be a source of funding for the museum.

The museum also created a number of ad hoc, temporary exhibits that included the Byte magazines, fractal images "The Colors of Chaos," and the insightful, ComputerWorld cartoonist, Richard Tennant's characterizations of the computer industry.

The lecture series continued with 50 more lectures by 1986, and a breakfast series was introduced that appealed to the Boston business community. In addition, a vigorous business was created utilizing the museum space in the lobbies and among the artifacts for private and corporate affairs including everything from serious seminars to birthday celebrations.

Appendix. Taxonomiies of Calcualtors and Memories

CLASS CALCULA

ORDER	**FAMILY** **-complexity**	**GENUS** **-structure**	**SPECIES**
Analog	single part	drawing instruments	protractor, pen etc.
		fixed rule	proportional rules
	2-3 part	gunter rule	gunter rule
		sector	sectors
		slide rule	straignt, circular, spiral, log-log
		level reference	gunnery level
		integrator	mileage reader
	multiple part	drawing instruments pantograph	
		level reference	quadrant, sextant etc
		integrator	planimeter, etc.
	complex	level reference	auto-pilot
		equation solver	harmonic analyzer etc tide predictor, etc
	programmable	diff. analyzer	Bush, Hartree
		analog computer	Genl Precision, etc.
Digital	single register	stone, bead	counting table,

			abacus, soroban, etc
		Pascal wheel	Pascal wheel, strip, keyed wheel
	two register	tab indicator	
		keyed wheels	Burroughs
	3-4 register	stepped wheel	Leibniz, arithmometers automatic stepped wheel
		rotary	Baldwin, Odhner, Curta, etc.
		motor-driven wh.	Monroe, Friden etc
		battery electronic	"pocket" calcs.
	complex	tabulator	Hollerith census, Powers-Samas
		equation-solver	ABC machine, pocket calculators,
		relay calculators	Bell Labs I difference engines
	programmable	relay calculators	Bell Labs II-IV, Z3-4
		analytic engine	Babbage, Harvard MKs
		tabulator	Hollerith, Powers,etc
		plug-board	ENIAC
		battery electronic pocket	

CLASS MEMORY

ORDER -interface	**FAMILY -technology**	**GENUS -structure of access**	**SPECIES**
Non-mech.	Physical state	Fixed-permanent	stone marks, Napiers
		Fixed-erasable	Quipu, beads, abacus
Writable or Readable	Paper	Fixed	
		Linear	scroll
		Cyclic	rolodex
		Random	book
	Mech. stable	Fixed	switches
		Linear	piano roll
		Cyclic	drum, disk
		Random	card
	Chem. stable	Linear	microfilm
		Random	microfiche, videodisc
	Magnetic	Random	rope
	Electric charge	Random	capacitor
	Electronic	Random	diode, semicon. rom

Writable & Readable	Mech. stable	Fixed	calculator registers
		Random	Zuse memory
	Wave storage	Cyclic	mercury, optical, & magneto-strictive
	Electric charge	Cyclic	Atanasoff drum
		Random	Williams tube, capacitor, MOS
	Magnetic flux	Linear	tape, wire
		Linear-cyclic	datacell
		Cyclic	fixed-head disk, drum
		Cyclic-linear	disk
		Random	core, disk
	Electronic stable	Fixed	flip/flop, relays, stepping switches
		Random	semiconductor array, relay array
	Chemically stable	Linear	photo store