2017

CORE

A Publication of
the Computer
History Museum

The Forces of Change in the Transformation Age
Making *Make Software: Change the World!*
Designing a New Space for Learning

Cover: ***Make Software: Change the World!*** **exhibition**
This page: Brain MRIs.

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The Forces of Change in the Transformation Age

As computing continues to impact our world at an unprecedented rate, CHM finds itself in a unique position as both a storyteller of this epic saga and as an institution in the midst of its own growth. Learn more as John C. Hollar defines the Transformation Age in parallel to the current expansion underway at CHM.

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Designing a New Space for Learning

Opening in fall 2017, CHM's new 3,000-square-foot Education Center will house the Museum's extensive slate of educational offerings, from K–12 workshops to programs for business leaders and young entrepreneurs. Go behind the scenes with Lauren Silver as she talks design, planning, and implementation of CHM's new learning space.

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Make Software: Change the World!

Preview CHM's newest major exhibition, *Make Software: Change the World!*, with an introduction by David C. Brock and a candid look at the exhibition's five-year development by Kirsten Tashev. Discover select artifacts and imagery from the exhibition's seven galleries and see examples of the interactive activities in our Stata Family Software Lab.

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Research & Insights @CHM

Research conducted by the Museum illuminates the transformation of computing in the world through careful analysis and interpretation. Gain unique insights into this transformation with articles by CHM's John Markoff, Marc Weber, and Hansen Hsu.

OPPOSITE: PHOTO BY KEN GLASER VIA MEDIA BAKERY

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INSIDE THE TRANSFORMATION

CEO'S LETTER

When Francis Ford Coppola agreed to accept Paramount Pictures' offer to write and direct *The Godfather* in the early 1970s, he painstakingly cut the pages out of Mario Puzo's epic novel and pasted them into a large, blank notebook. He annotated each page to produce the screenplay and the shooting script, and, from that text, Coppola distilled the story down to a one-word theme: succession. He later said that he believed every great project benefited from such focus and an easily understood theme.

In this issue of *Core*, you may discern a similar focus, and a similar theme: transformation. We have focused on transformation on two levels.

The first is the transformation computing is bringing to the world. Hardly any aspect of the world's economy, technological progress, social fabric, or political change is immune from computing's reach. In turn, computing has unleashed one of the greatest periods of creativity in human history. The story is epic, ongoing, and accelerating. It's a challenging time for the Computer History Museum (CHM), and yet also a time of exhilaration and heightening public interest.

The second level of transformation, I'm happy to say, is a major change in the Museum as an institution. We are well into a $30 million campaign that is transforming CHM on every level. We have opened a new Center for Software History to tell the continuing story of code's impact on the world—and to preserve and extend our world-class archive of operating systems, applications, and other creations by some of computing's greatest minds. Alongside that center, we've opened Exponential, a new center focusing on the history and impact of entrepreneurship as an element of computing's story. Both centers focus not only on what happened and what matters, but also on the people at the center of that change.

In January 2017, we opened a new $7 million exhibition, *Make Software: Change the World!*, which brings many of these stories to life by examining software's impact through the lens of seven iconic applications in use around the world. *Make Software* opened to great public acclaim and will anchor the west wing of our Shoreline building for years to come.

Adjacent to *Make Software*, a new multimillion-dollar Education Center is taking shape. When completed, it will give our rapidly growing education programs a permanent state-of-the-art home. It will also be equipped from end to end with the technology necessary to take our programs out to the world and to bring the world to our community of learners.

All of this is made possible by a legion of donors, our wonderful Board of Trustees, our staff, and our volunteer corps. They are the beating heart of our transformation. It's a privilege for me to present their work to you in this issue of *Core*. I hope you enjoy it.

Yours sincerely,

JOHN C. HOLLAR
PRESIDENT & CHIEF EXECUTIVE OFFICER

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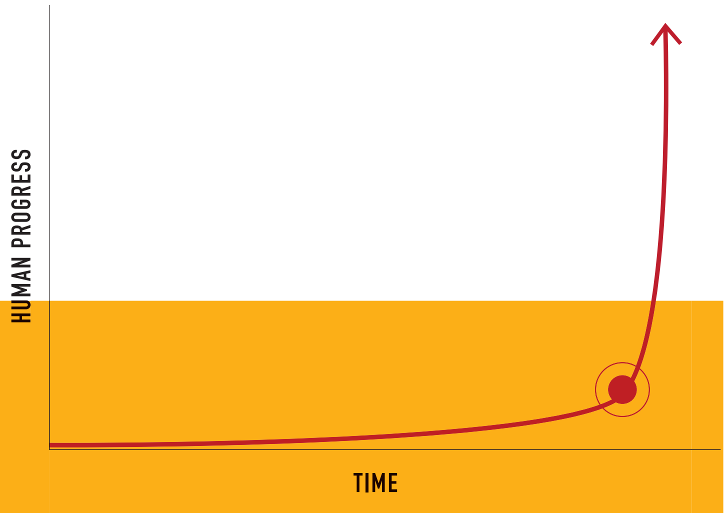

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MATION AGE

BY JOHN C. HOLLAR
PRESIDENT & CEO

The challenge and opportunity for CHM in the future is this: the Information Age is ending, and the Transformation Age is beginning. If we assign a one-word theme to the next strategic phase for the Museum, "transformation" is that word.

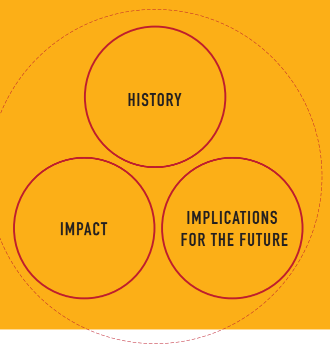
We live in a transformational era: the era when computing raced from nonexistent to ubiquitous. The transformation is technological, economic, and societal. It is universal, for the computing tools that enable transformation are now within reach of everyone on Earth. The resulting forces of change are permanent, and they are accelerating. Science shows that these forces will continue to accelerate far into the future as Moore's Law drives the capacity of computing at an inexorable, exponential rate. And because of computing's ubiquity, we are all part of the transformation now.

Measured against the span of recorded human history, the transformation has happened in the blink of an eye. Because of its pace, its historical roots are not widely understood. Its key lessons are essential to know, but also still emerging and not commonly shared. Its relentless acceleration can make its underlying principles hard to grasp and interpret. The implications for the future—economic, technical, societal, positive, negative—are a mere outline on the horizon.

In this context, the work required of the Museum is not simple. For two decades, however, we have believed it to be work worth doing. Today we know this work is growing in importance. It may appear to us today that we are standing on a plateau looking back on a vast period of computing history. It is more likely that we are merely witnessing the dawn of the even more profound change to come.

Building a Historical Platform

From our vantage point in the heart of Silicon Valley, CHM is the major institution in the world attempting to work out the meaning of this ongoing era of transformation—to identify, preserve, and present it even as the forces of change shape events in real time. We collect, exhibit, educate, publish, and story-tell for a singular purpose: we seek to enhance our understanding of this modern-day transformation. We do so by taking a 360-degree view of computing's history, its sweeping impact and the implications—technological, economic, and societal—for the future.



October 30, 2014
Museum Board presentation

Step by step, through these lenses, we will transform our understanding of computing—its history, its impact, and the implications for society in the future.

THE ENVIRONMENT

Regis McKenna,
"CHM: Chronicler or Driver?"
October 19, 2015
Museum Board presentation

"Static history and/or archives" will not turn on connected, diverse, mobile, distracted, over-saturated, living in the now, novelty-seeking consumers.

The museum of the future must turn itself inside out and make its content and role in the community it serves relevant to the present.

CHM's community has many time demands, choices of activities to participate in, distractions, constituents to please, as well as committed obligations.

The geography is expanding and diversifying yet Silicon Valley is still a synonym for innovation, entrepreneurship and view of the future—we can get attention but not necessarily their time and money.

If we view our work and our place in the world against the backdrop of today's ongoing transformation, the next strategic phase of the Museum must embrace and be more expansive in the following ways, beginning with history.

History is not only central to our mission, but a platform for all our work. History provides us, as scholars and educators, with a context for illuminating the forces of change that computing and human imagination have unleashed together. Our task is not to adopt a strategy that diminishes our work as collectors, chroniclers, and historians, but to reframe that work to meet the interpretive and educational requirements of impact today and implications tomorrow.

One important aspect of the CHM history platform is our collection of computing technology itself—the artifacts that exemplify how the world moved from the Antikythera mechanism of ancient Greece to the autonomous cars of 2016. Our world-class collection, which numbers more than 75,000 physical objects and more than 150,000 items of code and recorded media, gives us a rich "green field" that we can explore ourselves, open to others, and use to illustrate our interpretive work as we seek to bring understanding to our times.

A second important aspect of our platform is the stories of the men and women doing the pioneering work of computing—in both the past and today. They have become some of the most compelling and influential figures of the modern age. Their stories, their experiences, their vision, and their lessons for other generations help to explain the road we've traveled to today, the change we feel now, and the implications for tomorrow. We bring those figures to life in multiple ways, from exhibits to oral histories to live events.

History Alone is Not Enough: Impact and Implications

We now know as an institution that history alone is not enough. The demands of the field we chronicle and the demands of the modern-day museumgoer call for more. Our founding vision statement has always challenged us to explore the impact of computing on the human experience. This ongoing exploration of impact is the second vital element of our work.

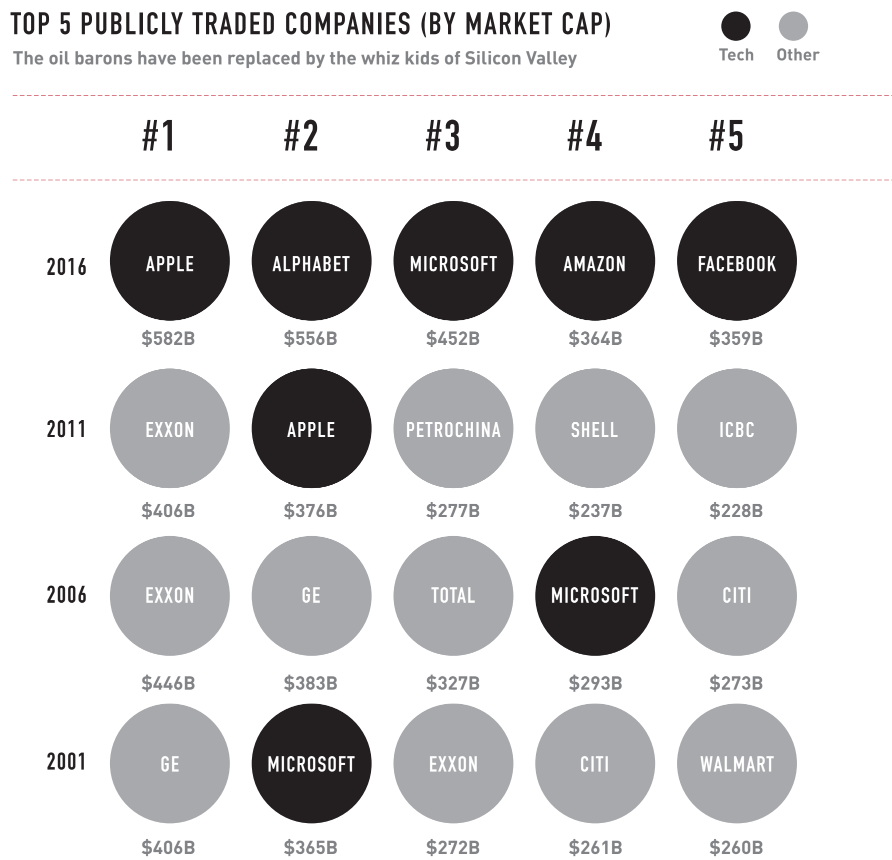
The impact story applies computing's history to the way we live today. It is "the history of now," from artificial intelligence and Photoshop imaging to global online gaming communities to spyware embedded in nuclear control systems.

The impact story must necessarily include the rise of entrepreneurs—their spectacular successes, their frequent failures, the lessons they've learned in the process, and the ecosystems in which they flourish. Entrepreneurs in the Transformation Age are some of the greatest problem-solvers of any age. When they pick the right problems, are sufficiently persistent and visionary, and encounter a stroke of luck, they produce transformational breakthroughs of historic proportions. Those breakthroughs, in turn, produce landmark companies and industries, just as their predecessors in other fields—manufacturing, petroleum, retailing, and finance—produced commercial enterprises that changed the global face of society in the last century. CHM's Exponential Center, the first museum center of its kind, will explore the people, companies, and communities transforming our world through innovation and entrepreneurship.

This impact story is more fundamental and more pervasive than simply business history. It is an impact story of creativity, persistence, and sweeping technical and societal change. Nowhere are those characteristics more evident in the computing field than in software. In 2001, only one software company—Microsoft—ranked as one of the five largest companies in the world as measured by market capitalization. In 2016, all five of the largest companies were either entirely rooted or deeply involved in "apps," search, e-commerce, operating systems, and other software-driven innovations—and each company, in turn, exerts a global influence. Companies that have tumbled off the list—GE, AT&T, Citi, and others—are striving to put software and applications at the center of their businesses and human resources for the future. We bring the history and impact of this transformation to light in multiple ways, with our new Center for Software History now at the heart of the effort.

The third essential element of the Museum's work is convening an ongoing conversation about the implications of these trends for the future. We seek to extend CHM's reputation as a neutral, skilled, and influential home for intelligent conversations about new directions in computing—the transformations they continue to produce and the possible change to come.

A major virtue of this strategic element is that it is media-centric and has global appeal. Our power to convene through live events also has a second virtue:



it allows us to illuminate future issues without taking an institutional position. Our brand, therefore, is created through our editorial choices—selecting the "right" stories to tell and attracting the "right" figures to tell them on stage. The third obvious virtue is live events produce an archive of almost evergreen content that can be repurposed in many ways. We can place it in multiple distribution partnerships and reversion it ourselves into many digital formats. This content, coupled with our other digital assets and artifacts, provides us with an almost limitless supply of media with which to reach both serious CHM enthusiasts and, in the words of Regis McKenna, "connected, diverse, mobile, over-saturated, living-in-the-now, novelty-seeking consumers."

Our Education Imperative: Humanities and Technology Intersect

The Museum's educational voice speaks with our audiences through our exhibits, our digital content, our live programming and, most of all, through our education programs. What began as a series of experimental programs in 2009 now flourishes as a connected system of formal and informal programs that engage every age level in problem-solving and computational thinking. As such, education at CHM draws on the lessons of the past and marries them with stories of impact and imagination to help learners of all ages recognize the transformational forces of change that are sweeping through the world.

Demand for these programs has surged since 2011—in part because the programs are fundamentally grounded in both STEM (science, technology, engineering, and mathematics) principles and in the liberal arts. Education at CHM is one part problem solving, one part design thinking, and one part understanding human behavior. CHM is a natural home for programs that meet the increasing need for learners inspired to pursue computer science, engineering, and mathematics—and it is also a natural home for programs that connect those concepts to broader principles drawn from history and other areas of the humanities and arts.

Even more broadly, the next phase of the Museum presents us with an opportunity to practice "transformation explained" as part of our larger educational mission for the broadest possible audience. Some of this work will be done through the Exponential Center's work with business executives and government officials from around the world, who are already asking for formal programs structured around the history and impact of entrepreneurship. Some of the work will be the responsibility of the Center for Software History, which is assimilating all of the Museum's extensive assets into new insights about software's impact on end users and makers alike. And some of the work will involve the expansion of our core education programs within the new IDEO-inspired Education Center taking shape on the Museum's first floor.

Transformation Moving Forward

In 2017, many of these strategic elements became vivid for the museum-going public with the unveiling of *Make Software: Change the World!*, a new $7 million exhibition and web portal. *Make Software* demonstrates many of the elements of our new strategy: the history, impact, and future implications of computing's transformative power. *Make Software* closes with the prophetic words of Marshall McLuhan: "We are what we behold. We shape our tools, and then our tools shape us." The work of both reflecting the history of our technological tools and interpreting how those tools are, in turn, shaping us will be at the center of our creative work as we move forward as an institution. ○

LAUNCHING EXPONENTIAL: A CENTER FOR ENTREPRENEURSHIP AND INNOVATION

CENTERS

BY MARGUERITE GONG HANCOCK
EXECUTIVE DIRECTOR,
EXPONENTIAL CENTER

In June 2016 CHM launched the Exponential Center, the first museum institution devoted to capturing the legacy—and advancing the future—of entrepreneurship and innovation in Silicon Valley and around the world. The Exponential Center informs and inspires the next generation of change-makers through five integrated initiatives: Collections & Exhibitions, Research & Insights, Education, Events, and Thought Leadership.

Why the Exponential Center?

"Entrepreneurs and computing go hand in hand. Across the world, people want to understand why that is, how it happens, what is special about the way it works in Silicon Valley, and how past entrepreneurship and innovation connects to the future," said John Hollar, the Museum's president and CEO. "The Exponential Center is preserving history, making forward-looking connections, and inspiring next generation entrepreneurs, innovators, and leaders."

Left to right: MyFitnessPal founders Mike and Albert Lee on stage with legendary venture capitalist John Doerr during the Exponential Center's launch symposium on June 3, 2016.

Many historians consider the Digital Age the most transformational era in recorded history—unprecedented in its power to change human experience in pace, personalization, scope, and scale. The result: technological innovation, economic value creation, and social impact affecting billions of people, including how they live, work, and play each day.

For more than the past half century, Silicon Valley has been epicenter and model for this activity, illustrated in generations of companies from Fairchild Semiconductor to Facebook. New companies create on average three million new jobs a year in the United States. Entrepreneurs, startups, and rapidly growing new businesses create 70 percent of all new jobs in the world and up to 90 percent in some emerging economies. Now innovation and entrepreneurship are a global phenomenon, spanning from Apple to Alphabet, from ARM to Alibaba.

Yet the Exponential Center is the first museum institution in Silicon Valley with this focus. The driving force for change in the Digital Age era is the combination of innovation and entrepreneurship. Each alone is potent; multiplied together they can create exponential progress. As part of CHM, in the heart of Silicon Valley, the Exponential Center is uniquely positioned to become the leading museum center exploring and engaging the people, companies, and communities driving exponential change. Exponential tells this worldwide story in new and compelling ways to help inspire and inform future changemakers.

Founding Advisors and Support

As part of a major strategic expansion of the Museum, the Exponential Center benefits from the active involvement of a circle of Silicon Valley veteran leaders. CHM Trustees Steve Smith and Dave Martin co-chaired the Founding Advisors to bring the Exponential Center to life. In November 2016 they passed the baton to Larry Sonsini, CHM trustee and chair of law firm Wilson Sonsini Rosati & Goodrich, to chair the Exponential Advisory Committee for the next phase of growth and impact.

To date, $2.75 million of early stage support has been raised as part of a $10 million campaign for the first phase of the center's development and programs. Major funders include Veritas Software founder Mark and Debra Leslie, pioneering venture capitalist Franklin "Pitch" and Catherine Johnson, and Venrock veteran Ray and Meredith Rothrock. They are joined by a growing circle of generous supporters of leaders from Silicon Valley and beyond.

Early Progress in Five Key Areas of Work

Already the Exponential Center has started to deliver on its mission and five integrated initiatives. Below is a selection of highlights from each area.

Collections & Exhibitions

Oral Histories

- Gordon Moore (founder) and Arthur Rock (venture capitalist) on Intel
- John Chambers (former CEO, Cisco) and Don Valentine (venture capitalist, Sequoia) on Cisco
- Roger Smith and Bob Medearis, co-founders, Silicon Valley Bank
- Gil Shwed, founder, Checkpoint Software
- Pradip Sindhu, founder, Juniper Networks

Artifacts

- First business plans of NetApp from former CEO Dan Warmenhoven and of Sun Microsystems from investor Gary Kalbach
- 85 original ads from early years of Intel and Apple, donated by Regis McKenna

Exhibit

"1 to 1 Billion" display, featuring eight iconic artifacts from the Museum's collection that illustrate how one idea, combined with entrepreneurial spirit, can touch a billion people, create a billion devices, or generate a billion dollars. Artifacts included an HP Model 200 Oscillator (1939); a selection of Fairchild engineering notebooks (1957); a roll of Micro-Soft Altair BASIC paper tape; an early Apple advertising proof alongside the company's preliminary offering memo (1978); a Cisco AGS Router (1986); a Facebook motherboard (2011); and a Google bicycle (2011).

Events

Exponential and its associated NextGen Advisory Board have organized 17 events, which have attracted more than 2,500 people, with attendees from more than 350 companies and organizations. Selected events include:

- "Alibaba and Jack Ma: Beyond E-commerce and China—Implications for Silicon Valley," with author Duncan Clark
- "Pioneers of the Possible: Women Entrepreneurs on Innovation and Impact," with DFJ's Heidi Roizen and Cloudflare's Michelle Zatlyn
- "Day of the Dead: Postmortems on Silicon Valley Failures," with Garage Technology Ventures' Bill Reichert, CrowdStreet's Kim Polese, and Twitch's Justin Kan (jointly organized with NextGen)
- "The Next Billion," with Kiva Executive Chair Julie Hanna

Education and Research & Insights

In 2016 Exponential welcomed attendees from 35 countries for its executive education briefings and events. The center also started developing a new educational curriculum with content that includes video clips and discussion guides.

Thought Leadership

Private roundtables have included discussions for Silicon Valley leaders with US Department of Commerce Undersecretary Stefan Selig as well as US Chief Data Scientist DJ Patil. Exponential has also hosted international government leaders, such as Sweden's HRH Princess Victoria, leading entrepreneurs from China, and consuls general from more than 30 countries.

Looking ahead, the Exponential Center will build on positive momentum to expand its work and impact through its five areas of work at the Museum as well as through extensive collaboration and partnerships. The center is a platform to collect and share the legacy and lessons of exponential impact in the past. Exponential is also at the nexus for innovators and entrepreneurs who will lead the way in the future to create new technologies, new economic value creation, and new ways to improve people's lives around the world. As summed up by iconic venture capitalist John Doerr: "What we know and what we believe about Silicon Valley is the following: Silicon Valley is not a place. It is a state of mind. It can be everywhere. It can uplift everyone. That is the idea of Exponential." ○

About the Exponential Center: The Exponential Center at the Computer History Museum (CHM) is capturing the legacy—and advancing the future—of entrepreneurship and innovation in Silicon Valley and around the world. The center explores the people, companies, and communities that are transforming the human experience through technology innovation, economic value creation, and social impact. The center's work focuses on five integrated initiatives: collections and exhibitions, research and insights, education, events, and thought leadership. Our mission: to inform, influence, and inspire the next generation of innovators, entrepreneurs, and leaders changing the world. Visit our website: computerhistory.org/exponential.

Exponential Center Executive Director Marguerite Gong Hancock with Renault executives after a briefing on Silicon Valley startup culture and digital innovation, June 2015.

In March 2015, the Exponential Center hosted its first "360" event with an in-depth look at NetApp.

HONORING THE FOUNDERS AND BUILDERS OF THE DIGITAL AGE

BY MARGUERITE GONG HANCOCK
EXECUTIVE DIRECTOR, EXPONENTIAL CENTER

On June 2, 2016, Exponential hosted its launch gala, "1 to 1 Billion: Celebrating the Founders and Builders of the Digital Age." The center convened 250 founders, partners, and early team members involved in more than 400 companies, including Fairchild, Intel, Google, Apple, Cisco, Microsoft, Motorola, Intuit, NVIDIA, SanDisk, Sunpower, 23andme, and Intuitive Surgical. Managing partners and senior leaders also participated from leading institutions in the entrepreneurial ecosystem, such as Stanford University, UC Berkeley, Draper Fisher Jurvetson, Khosla Ventures, NEA, Sequoia, Fenwick & West, and Wilson Sonsini Goodrich & Rosati.

Six pioneering honorees, who established the foundation of Silicon Valley's entrepreneurial economy, shared their insights throughout the event:

- Gordon Moore, on becoming an "accidental entrepreneur"
- Jay Last, on the "driving force for the original transistor silicon business"
- Arthur Rock, on the importance of "having luck early"
- Regis McKenna, on "helping people around the world better understand what it is to be an entrepreneur"
- Larry Sonsini, on "capturing and sustaining the recipe of Silicon Valley"
- John Doerr, on Silicon Valley as "a state of mind" that "can uplift everyone"

Special tributes honoring Intuit CEO Bill Campbell and Intel co-founder and CEO Andy Grove were given by Numenta CEO Donna Dubinsky and Breyer Capital CEO Jim Breyer.

Reflecting on the event, the vice president of strategy at a multibillion dollar firm at the intersection of robotics and health, shared: "The honorees were some of Silicon Valley's titans . . . who were instrumental in building the culture of entrepreneurship. . . . This is part of what is so amazing about exponential change. The origins of Silicon Valley were wandering around the room, and the changes brought on by the Digital Age have happened so rapidly that it was possible for them to be alive to see the worldwide effects of the things they had done."

The Exponential Center's launch marked the beginning of its major effort to capture the legacy and lessons of the people and companies who have founded and built the Digital Age. ○

EXHIBITING A HISTORY OF ENTREPRENEURIAL GROWTH & INNOVATION

BY DAVID LAWS
SEMICONDUCTOR CURATOR

Sixty years after its founding in 1957, Fairchild Semiconductor Corporation is celebrated as "The First Trillion Dollar Start-up."[1] Through an unprecedented series of technical, business, and cultural innovations, the company spawned hundreds of ventures that established Silicon Valley as a world center of entrepreneurial activity and technological leadership. Although the firm's market valuation never exceeded $2.5 billion, its surviving combined progeny have been estimated to be worth over $2 trillion.

Fairchild's role in stimulating the explosive entrepreneurial growth of Silicon Valley since the 1960s is the basis for the Museum's exhibit, *The Trillion Dollar Startup: Fairchild, Fairchildren, and the Family Tree of Silicon Valley*, developed by the Exponential Center and launched on December 20, 2016.

The exhibit features a display case with the patent notebooks of Jean Hoerni, Gordon Moore, and Robert Noyce, chosen from the Museum's collection of nearly 1,300 Fairchild patent and laboratory notebooks. These three notebooks exemplify key discoveries—like the first expression of the planar process—that transformed the Valley from just another emerging hub of the electronics industry into a world-renowned center of innovation and entrepreneurial activity.

Growing out of those Fairchild roots, a towering 30-foot-high mural in the CHM lobby illustrates a giant high-tech tree, laden with a harvest of 36 spin-off companies selected to represent the hundreds of successful ventures spanning six generations of key Silicon Valley technology eras, from semiconductors to social media. Fairchild alumni founded influential tech firms such as Intel and AMD in addition to pioneering venture capital firms Sequoia Capital and Kleiner Perkins Caufield Byers. Today Google, Facebook and more than 92 public companies can be traced back to Fairchild, which fostered multiple generations of high-value innovative companies and the culture of entrepreneurial growth that today we celebrate as the Silicon Valley way. ○

[1] Rhett Morris, "How Did Silicon Valley Become Silicon Valley," Endeavor Insight, (July 29, 2014).

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FORTRAN

BY DAVID C. BROCK
DIRECTOR, CENTER FOR SOFTWARE HISTORY

INTRODUCING THE CENTER FOR SOFTWARE HISTORY

No people, no code. Apps, programs, code, software—call it what you will, it is created by people. Software is what computers do, from supercomputers to smartphones. Human lives everywhere are shaped by people's use of software, and this in just a single lifetime, the seven decades since computers ran the earliest programs.

At the Center for Software History, our teams build, secure, and study the Museum's remarkable collections to understand and tell the story of software. Our mission is to preserve this history for posterity while putting it to work today, asking where we are, where we have been, and where we might be going.

Software—as pattern, algorithm, service, or even as thought—seems intangible. But from another perspective, software is concrete, even personal. Software history is built of people-centered stories because always and everywhere, it is ultimately people who create software. The existence of code reflects the story of the people who made it.

The profound social implications of software are, will, and have always been the consequence of people's decisions in making and using code. In the stories of people, then, lie the technical, business, intellectual, social, and cultural histories of software—from timesharing to the cloud, from custom code to packaged programs, from developers to entrepreneurs, from mainframes to microprocessors.

Computer programs are inherently performative. People create code so that a computer might run it. The fullest meaning of software can be found in its performance, which presents great challenges and opportunities for software history. At the Center for Software History, we are simultaneously exploring the pursuit of these people-centered stories and filming software in action to preserve and present software history and its implications to diverse publics.

But why a Center for Software History now, and why at CHM? Foremost is the tremendous opportunity to build on the momentum of *Make Software: Change the World!*, the most ambitious museum exhibition on the story of computer software undertaken in recent years, perhaps ever. Another positive motivation is the desire to build upon and make best use of the Museum's impressive existing holdings of software—ranging from the first magnetic tapes from Whirlwind to well over a hundred thousand floppy disks of personal computer software—as well as oral histories, archival collections, and audiovisual materials documenting software history.

There is, of course, a profound concern spurring the software center and its work: the fragility of our digital heritage. Historical software is ironically at great risk for loss, and the challenges of preserving it and making it accessible are formidable, without clear solutions. CHM is one of a very few cultural institutions worldwide actively collecting software for permanent preservation. Similarly, the Center for Software History may be the only organization devoted to the pursuit of collections-based software history, one that incorporates insights from examining code, software performance, documents, oral history, publications, and audiovisual materials alike. With this unique position comes the opportunity to break new ground and serve a global community that is looking at preserving and interpreting its digital heritage.

At the Center for Software History, we are at work on two pilot projects that make good use of particularly rich clusters of materials in the Museum's collections spanning hardware, software, documents, photographs, audiovisual materials, oral histories, and the possibility of running historical soft-

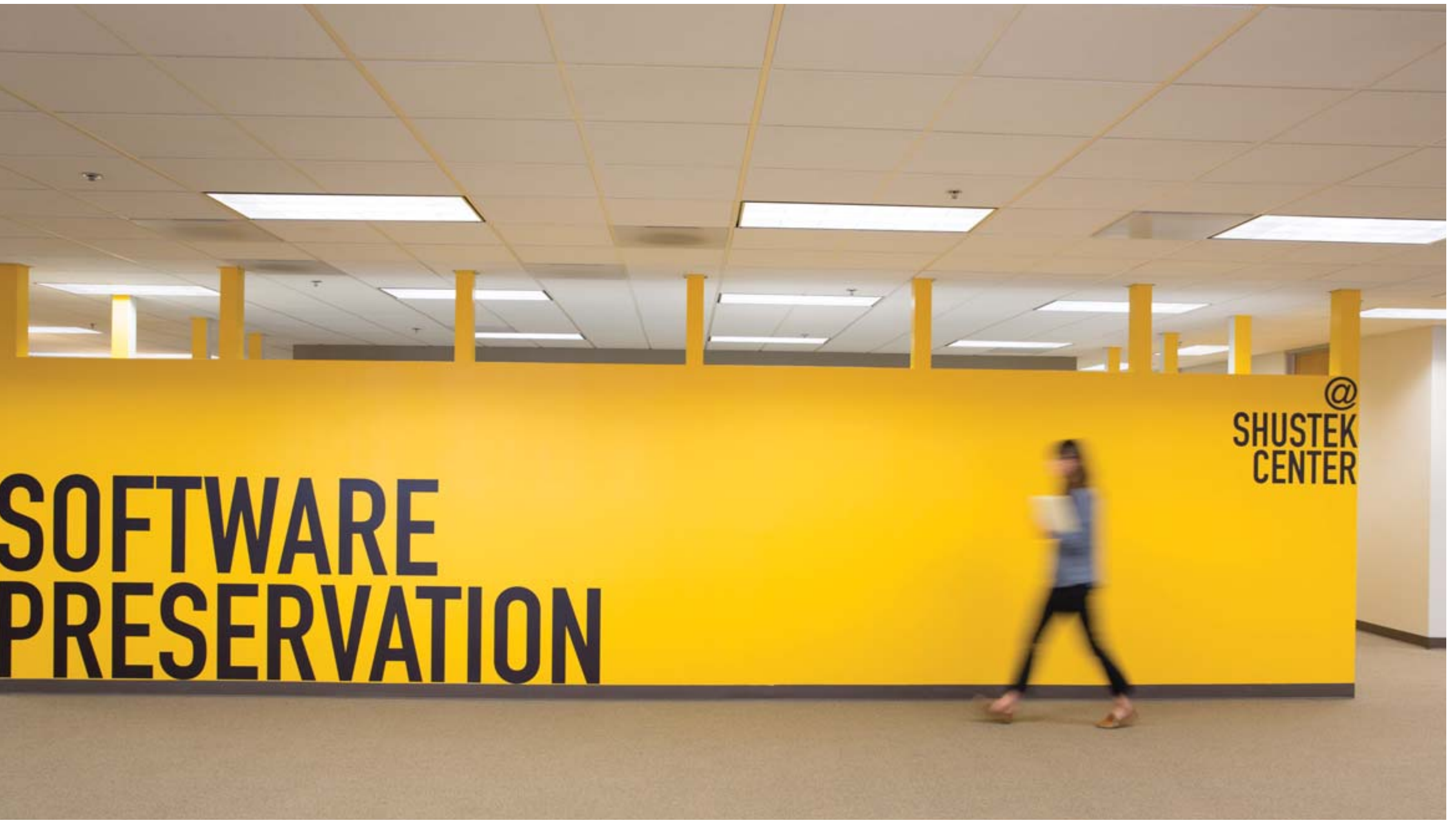
The Center for Software History collects and preserves software stored on a full range of historical media, including paper punched cards as pictured here.

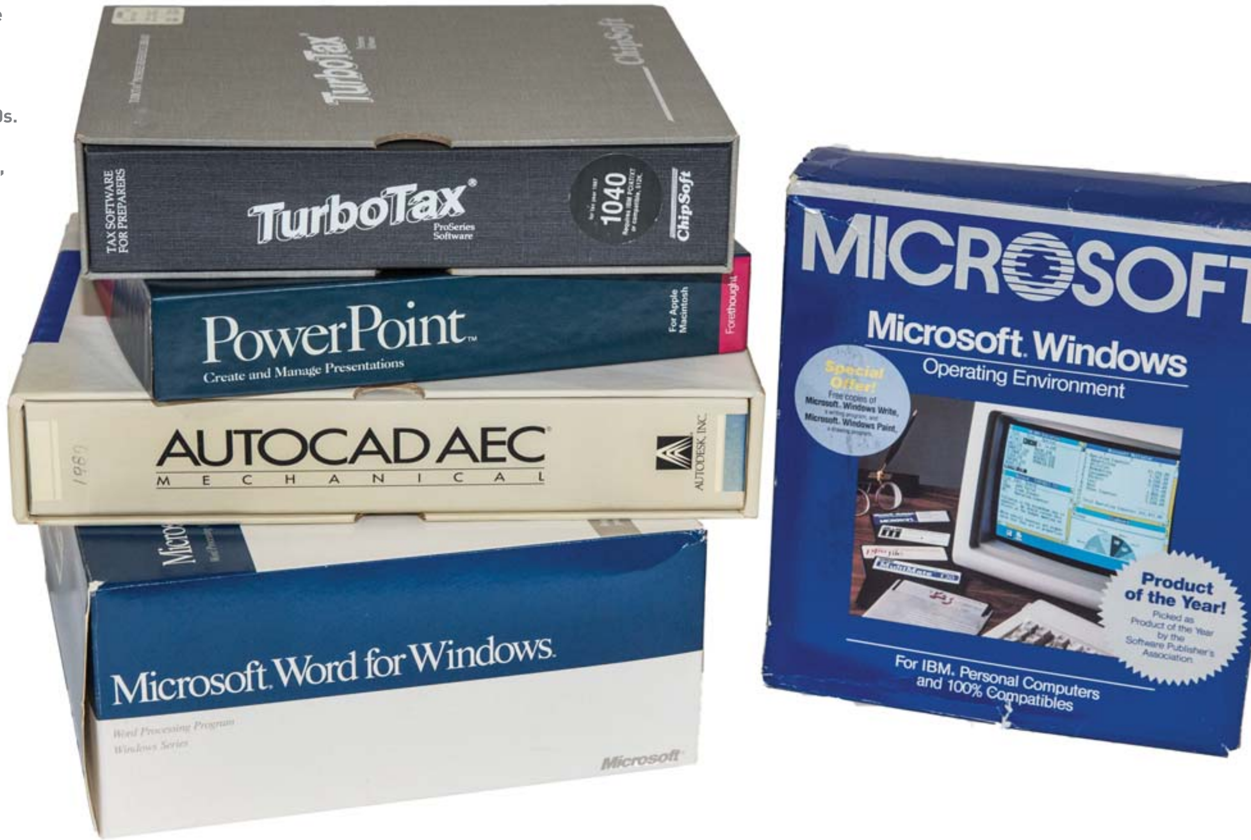
ware on its original hardware. These are pilot projects in the sense that we are charting a new path for collections-based software history, and we expect missteps along with successes. Our experience in these pilot projects will help guide our future projects.

We began with an effort to document and interpret the origins, development, and expanding use of PowerPoint. PowerPoint, and its rivals in the realm of presentation software, have become ubiquitous cultural tools. Where did they come from? Who made them? How did they work technically and socially? Our PowerPoint Project is using oral history, text archives, source code listings, video documentation of historical software in action, and digital preservation to get at these questions. We are beginning to communicate what we have learned and preserved through the *@CHM* blog. Our second, more ambitious Alto System Project is detailed elsewhere in this edition of *Core*.

With a people-centered approach to software history and our projects, the software center is actively contributing to the Museum's vibrant oral history program. The Museum's oral histories are an incredible historical resource in their own right and serve as vital resources for interpretation and exhibits. As a collections-based institution, the curatorial team of the software center—Hansen Hsu, Al Kossow, and myself—are actively building the Museum's software holdings, with an approach that could be described as "comprehensively representative." That is, we are looking to collect historically important software—source code and executables—as well

Software preservation at CHM's new Shustek Center includes software curator Al Kossow's facility for the recovery of data from the oldest of media.



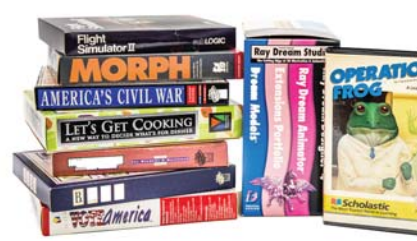


The Museum's vast software collection includes, among scores of others, landmark examples of packaged business software from the 1980s. Pictured here: TurboTax, PowerPoint, AutoCAD, Word, and Windows.

as software that is representative of major types or genres of computer programs across possible taxonomies, geographies, and eras.

The work of the Center for Software History's curatorial team builds on a longstanding tradition of engagement with the history of software and the software industry at CHM. The Museum's collection of tens of thousands of computer programs from a variety of media was built from large donations from major collectors and institutions, as well as smaller donations from individual contributors and members. The Internet History Program has pursued years of collecting, oral history, and interpretive work. The Museum's Software Preservation Group assembled deep, curated collections of source code and early software. Substantial text and AV collections connected to the story of software in the Museum collection came from years of efforts by the Museum's curators and from the Museum's Software Industry Special Interest Group (SI SIG). The SI SIG, along with other Museum volunteers and staff, built a remarkable collection of hundreds of software-related oral histories, freely and openly accessible today through the Museum's website.

The Center for Software History has, in addition to a curatorial team, an expanding and active digital collection team, responsible not only for the long-term digital preservation of historical software, but also for all the Museum's digital assets from oral history recordings to event video, and from scanned papers and photographs to born-digital files. Our digital collection team includes Paula Jabloner, director of digital collections; Andrew Berger, senior digital archivist; and Elena Colón-Marrero, digital processing archivist. For years, the Museum's efforts at software preservation by collecting programs on original storage media has been accompanied by efforts to safely "read" this data, and preserve it as well. Today, the Center for Software History's digital collections team is actively digging into the technical, legal, and logistical challenges for the long-term preservation and accessibility of software.



Games, encyclopedias, and educational programs in the Museum's collection document the development of software as a resource for recreation and learning.

Punched paper tape was a dominant medium for the storage of programs and information from the emergence of digital computing through the 1970s, from Colossus to Altair.

Importantly, the software center is undertaking what we call "interpretive outreach" across several fronts. As part of CHM's live programming, we are pursuing speakers to address the theme of "Why Software Matters" on everything from world hunger to space exploration and climate science. We are hosting and helping to organize a significant conference of computing historians, *Command Lines*, with a software focus. We are collaborating with the SI SIG on two workshops, one of software industry historians to assess the state and direction of the field, and the other of desktop publishing pioneers. We are presenting our work and experiences on our pilot projects and software presentation at scholarly conferences like the Society for the History of Technology and the Society for the Social Studies of Science. In early planning stages are collaborations with our education team for opportunities to draw on our Alto System Project to build engaging experiences of software history in the Museum's new Education Center.

From collections-based software history to software preservation and interpretive outreach, all are challenges for which no other organization or institution has established definitive best practice. The Center for Software History will be leading by example, with our failures and successes leading to our own learning and the benefit of broader communities concerned with preserving our digital heritage. ○

About the Center for Software History: The purpose of the Center for Software History at the Computer History Museum (CHM) is to collect, preserve, and interpret the history of software and its transformational effects on global society.

Software is what a computer does. The existence of code reflects the story of the people who made it. The transformational effects of software are the consequences of people's creation and use of code. In the stories of these people lie the technical, business, and cultural histories of software—from timesharing services to the cloud, from custom code to packaged programs, from developers to entrepreneurs, from smartphones to supercomputers.

The center is exploring these people-centered stories, documenting software-in-action, and leveraging CHM's rich collections to tell the story of software, preserve this history, and put it to work today for gauging where we are, where we have been, and where we might be going.

For details, see computerhistory.org/softwarehistory.

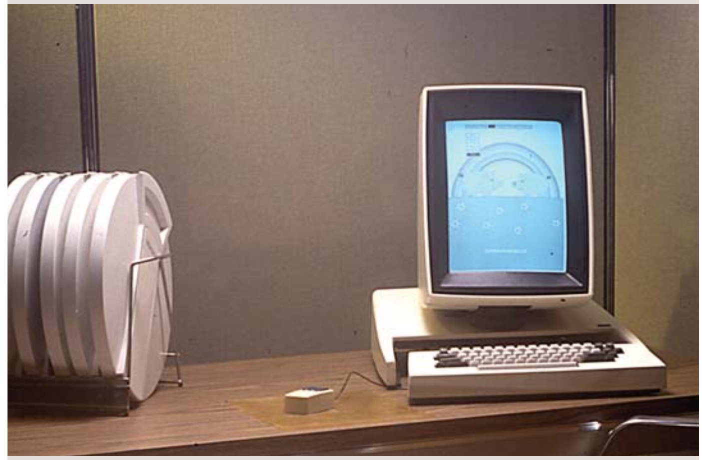
PRESERVING SOFTWARE WITH DIGITAL FORENSICS

BY ELENA COLÓN-MARRERO
DIGITAL PROCESSING ARCHIVIST

CHM is using digital forensics to preserve the vast amounts of historical software found within its collection. Digital forensics, originally developed for criminal investigations, has emerged as a promising source of tools and approaches for facilitating digital preservation. The tenets of digital authenticity, accountability, and accessibility translate to the work done in many museums and archives. At CHM, we're developing digital capture and cataloging workflows to guide our preservation work. The creation of digital forensics workstations will allow the Museum to preserve the thousands of pieces of software in our collection at a faster rate. Without these additional resources, our ability to make the software in our collection accessible to researchers and curators is hindered.

In a cooperative effort between IT and the digital collections group, two custom digital forensics workstations were built to conduct CHM's digital preservation work, including capture, read, and process disk images of 5.25-inch floppy disks, 3.5-inch floppy disks, and CD-ROMs. The first workstation is a Windows-based computer and the second is a Linux computer mounted with BitCurator, an open source Ubuntu environment specially designed for archives. Materials processed on these machines will be placed into the Museum's digital repository for safekeeping. Processed software will be cataloged and described to aid discovery.

RESTORING YESTERDAY'S COMPUTER SYSTEM OF TOMORROW: THE ALTO SYSTEM PROJECT



BY DAVID C. BROCK
DIRECTOR, CENTER FOR SOFTWARE HISTORY

Between 1972 and 1978, staff of the Xerox Palo Alto Research Center (PARC) created what Butler Lampson (one of these staff) later described as a "whole complex of hardware and software," also known as the "Alto system." Weaving together and creatively extending many important threads from computer science and engineering research, the Alto system and its manifestation of what its makers called "personal distributed computing" served as an exemplar, inspiration, and template for much of personal computing that would follow. Direct lines of historical development lead from the Alto system to everything from the Apple Macintosh to Microsoft Windows, from laser printers to the Ethernet, from Adobe Postscript and PDF to Microsoft Word, and many, many others.

These lines of development were intentional, but not specifically foreseen. The philosophy of the Alto system's builders was that it would serve as a "time machine"—it would be "tomorrow's" system, but in hand today. In short, the Alto hardware represented what the PARC staff believed would be commercially viable a decade hence, that is, sometime in mid-1980s. With it, they would develop the software and practices of the "office of the future." The Alto system would allow them to live in a future that they would thereby and simultaneously help to create. One could reasonably argue that this is precisely what happened.

The Center for Software History's Alto System Project seeks to restore, as well as we are able, yesterday's "computer system of tomorrow." With functioning Alto hardware and original Alto software, we plan to use archival-grade video to document and preserve the performance of the Alto system, including demonstrations and discussions with its builders, for today's future.

BY KAREN KROSLOWITZ
DIRECTOR OF COLLECTIONS

NEW SHUSTEK CENTER PROMOTES ACQUISITIONS, ARCHIVES, AND ACCESS

Every exhibition deserves a beautiful space. The opening in January 2017 of *Make Software: Change the World!* brings renovations to CHM, just as the Revolution exhibition did in 2010. Coupled with the Museum's ongoing successes in educational and public programs and event venue rentals, the strategy to maintain the Mountain View location as its forward-facing flagship was an obvious choice. Therefore, once again, the recent acquisitions and archives housed in what would become the new exhibition needed to be moved offsite.

Since 2007, the Museum has been consolidating its hardware and ephemera collections in an offsite facility in Milpitas. Its high bay racks are best suited to the storage of expansive mainframe systems, supercomputers, and other objects that require infrequent access. But it's incompatible with archives—the software, documents, images, and oral histories that researchers request most often. The bulk of

The Shustek Center is a state-of-the-art research and storage facility, housing the Museum's acquisitions, archives, software preservation, and research operations.

After a surprise unveiling in August 2014, Board of Trustees Chair Len Shustek poses with early design concepts of the Shustek Center.

unprocessed archival collections were inaccessibly stored in Milpitas and, in its existing configuration, the facility was reaching its maximum capacity. Clearly, it was time to acquire a third building.

Immediately following the board's approval in 2014 to purchase another property, Trustee Donna Dubinsky hatched a secret plan to name the building for her husband and Museum board chair Len Shustek in honor of his leadership of the Museum for more than 20 years. Naturally, Donna's idea was well received and she personally began fundraising. In a few short months, Donna had raised the majority of the capital needed.

In August, a small group of donors and staff gathered with Donna and President and CEO John Hollar to unveil a mock-up of the Shustek Center, complete with dedicated parking for Len's beloved Tesla. To everyone's delight, the covert plan was still a secret. Len was visibly surprised and delighted by the honor.

By November, Vice President of Operations Gary Matsushita identified a possible East Bay property. Several Collections staff and trustees toured the freshly painted office building. At 50,000 square feet, it was larger than originally planned but satisfied several requirements: staff offices, a research room, and a loading dock for receiving new acquisitions, plus large open areas where several exciting archives processing projects could be achieved simultaneously. Considering future growth of the archives and staff, the board's Finance Committee with CEO John Hollar and CFO George Holmes confirmed the purchase was a sound investment.

In February 2015, the Museum officially purchased the property at 48431 Milmont Drive in Fremont. Over the course of several months the building then underwent systems upgrades and was outfitted with new office furniture, lighting, and shelving. In December, it was finally ready for collections and staff to move in! Registrars, archivists, and professional movers packed boxes of archives and cartfuls of artifacts from Mountain View and shifted pallets of boxed documents and software from Milpitas.

By April 2016, several staff had relocated to new offices. New acquisitions receiving and cataloging operations also relocated to the Shustek Center, so several volunteers settled in to assist. For the first time since the Museum was established on the West Coast, defined workspaces for collections processing properly equipped with large tables for sorting and packing plus a modern, dedicated scanning lab were finally established at the Shustek Center.

One of those defined spaces is the Bernard L. Peuto Software Preservation Lab. The Software Preservation Lab is a dedicated laboratory where software curator Al Kossow processes and reads the Museum's historical software collections, in a variety of formats from paper tape and punched cards to magnetic disks and more. Once read, files are preserved in the Museum's digital repository for long-term preservation. As a means of short-term preventive conservation, all magnetic-, polyester-, and acetate-based media, such as "mag tape" and photographic films, will be physically stored in a new media vault where the climate can be strictly regulated. Mobile compact shelving maximizes space and houses these materials.

As with software, accessibility to CHM documents and images is also continuously increasing. Of particular interest to academics and hobbyists alike, the Shustek Center's Research Room is open by appointment to anyone eager to delve into the Museum's unique holdings. With funding from the Andrew W. Mellon Foundation administered by the Council on Library and Information Resources (CLIR), the Museum's first major archives processing project has been underway since April 2015. Designed by Senior Archives Manager Sara Lott to significantly reduce text and photographic backlog through the widely employed archival "more product, less process" approach. The two-year project requires the efforts of two full-time archivists and a small army of volunteers to sort and organize documents, transcribe identifiers for the people and places depicted in still images, and create catalog records. The largest collection is from Digital Equipment Corporation (DEC): nearly 700 boxes of text, 7 pallets of boxed moving images, and 19 four-drawer filing cabinets of photographic prints and negatives. The DEC collection is one of 26 being processed as part of the CLIR grant, which also includes the papers of Adele Goldberg, Esther Dyson, Jim Porter, and Community Memory. Researchers and museums have quickly shown interest in these previously hidden materials.

Without the elbow room now available at the Shustek Center, the Museum could not simultaneously uncover the archives most closely associated with the software industry. In an intensive one-year effort initiated with funds raised by the Museum's Software Industry Special Interest Group, an archivist is processing 50 linear feet of documents, slides, and software and more than 800 digital files. As with the CLIR grant, finding aids for each minimally processed collection are published on the Museum's website, on the Online Archive of California, and on WorldCat via the National Union Catalog of Manuscript Collections, where researchers can easily locate the records via any search engine.

The Shustek Center provides study space for visiting scholars and climate-controlled storage for the Museum's digital and archival collections.

Dedicated workspaces alongside digitization and scanning labs promote greater access and preservation of CHM's world-class collections. Here, Project Archivist Bo Doub studies a negative from the Digital Equipment Corporation corporate photo library.

During the opening of the building in September 2016, Len recounted how he has always eschewed naming spaces for himself. However, he gratefully accepts this dedication as an honor to his family's legacy and its unusual name, about which the genealogical research he has done provides only a partial history. Whether for family genealogy or computer history, preservation of and access to archives is core to our ability to know our roots, and benefits all of society. Thank you to Len, Donna, and all the supporters who, through the creation of the Shustek Center, leave for all a great contribution to the historical record. ○

About the Shustek Center:
The Shustek Center, located in California's Silicon Valley, is the state-of-the-art research and storage facility of the Computer History Museum (CHM). Established in 2015 and named for Museum founder and chairman Len Shustek, the Shustek Center houses the Museum's acquisitions, archives, software preservation, and research operations. With study space for visiting scholars, climate-controlled storage for digital and archival collections, artifact acquisitions receiving, and digitization workstations, the Shustek Center promotes greater access and preservation of CHM's world-class collections. Access by appointment only.

CHM IN THE NEWS

BY DAG SPICER
SENIOR CURATOR

As computer technology continues to spread around the world and into our daily lives, CHM has become a trusted source among the world's media for factual accuracy and a global, long-term perspective on computing and its implications.

Over the last year, CHM curators have responded to inquiries from dozens of journalists, editors, and media outlets, including the *Guardian*, the *New York Times*, NPR, Agence France-Presse, Voice of America, Travel Channel, *Fast Company*, *USA Today*, *Popular Mechanics*, Bloomberg, and many more.

A few brief examples. Senior Curator Dag Spicer and Curator Hansen Hsu consulted on two articles on Chinese supercomputing for the scholarly journals *Foreign Affairs* and *Foreign Policy*. Curator Chris Garcia spoke about computing and the countercultural scene of the San Francisco Bay Area in the 1970s with the *Financial Times*. Additionally, Marc Weber, curatorial director of CHM's Internet History Program, contributed to articles on internet history for the *New York Times*, the *Guardian*, and the Discovery Channel. Director of the Center for Software History David C. Brock also consulted with National Public Radio (NPR) on their "Marketplace Tech" radio show about the future of Moore's Law.

Keeping abreast of the latest technologies and their roots in our past, CHM provides a unique perspective to the world's media, linking today's technologies to the histories of the people and institutions who made them happen. As the world continues to make sense of our rapidly changing world, CHM curators honor the role of history in their interviews as a guidepost to the present and the future. ○

CHM Media Interactions
KGO/CBS
San Francisco Chronicle
Guardian
USA Today
Discovery Channel
Fast Company
The Financial Times
Travel Channel
Foreign Affairs
Foreign Policy
Voice of America
San Jose Mercury News
Agence France-Presse
Popular Mechanics
The New York Times
National Public Radio (NPR)
The Wall Street Journal

THE DIGITAL REPOSITORY AT CHM

BY ANDREW BERGER
SENIOR DIGITAL ARCHIVIST

Launched in April 2015, CHM's digital repository provides stable, long-term storage for the Museum's digital collections. It is designed to meet the complex needs of CHM's growing collections, especially the moving image and software collections. Data is stored in the form of archival packages, which can be retrieved by authorized users as needed. The system also includes built-in monitoring capabilities that allow staff to check the status of the data.

In line with data storage best practices, the repository does not have a single physical location but is spread across the Museum's main Shoreline campus and the Shustek Center in Fremont. In terms of hardware, the repository consists of three servers plus a tape backup system. Each server contains a redundant array of disks and uses a file system called ZFS, which provides built-in protection against data corruption. These multiple layers of redundancy mean that the repository never stores just one copy of the collection, which reduces the risk that a failure of part of the system will result in permanent data loss. The repository's current capacity is approximately 114 TB and can be scaled up as needed.

Ultimately, the goal of the repository is not just to provide storage, but to ensure that the Museum's digital collections remain accessible into the future. ○

EDUCATION

DESIGNING A NEW SPACE FOR LEARNING

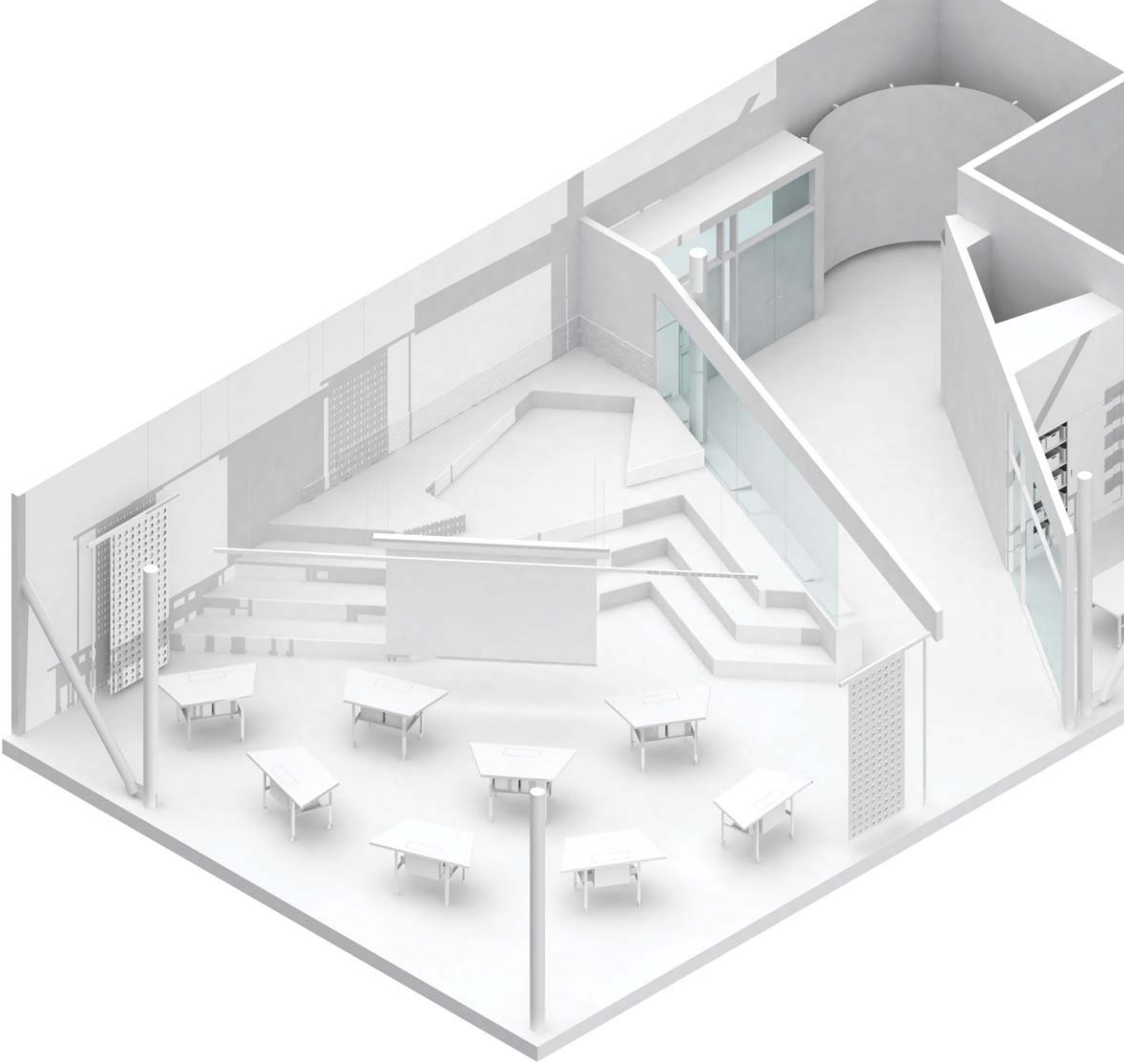
A NEW ERA FOR EDUCATION AT CHM

BY LAUREN SILVER
VICE PRESIDENT OF EDUCATION

Later this year, the Museum will open a 3,000 square-foot Education Center on the first floor, directly adjacent to *Make Software: Change the World!* This is a significant milestone in the evolution of CHM as a world-class institution greatly advancing our educational mission to enable all people to make personal connections with the history of computing and understand technology's role in shaping our world. Every facet of the Education Center will exemplify the collaborative, inquiry-based approach to teaching and learning that is the Museum's strength and maximize opportunities for connected, technology-rich, learner-centered education that are the hallmarks of education in the 21st century.

Fundamental to the Education Center is the Museum-wide recognition that learning is at the heart of everything we do. From exhibitions to live programs, from events and research by our Center for Software History and Exponential Center to public tours and workshops for students, educators, and families, CHM is all about presenting, questioning, and experiencing transformational technologies, people, and ideas and their impact on our lives. Since the opening of *Revolution: The First 2000 Years of Computing* in 2011, public demand for these opportunities has grown significantly, and our commitment to provide them has expanded accordingly. The decision to create a dedicated space for educational activities is a natural extension of this commitment.

The field of education is undergoing radical change, much of it driven by computing, the effects of which are not yet well understood. As an educational institution focused on the impact and implications of technology,

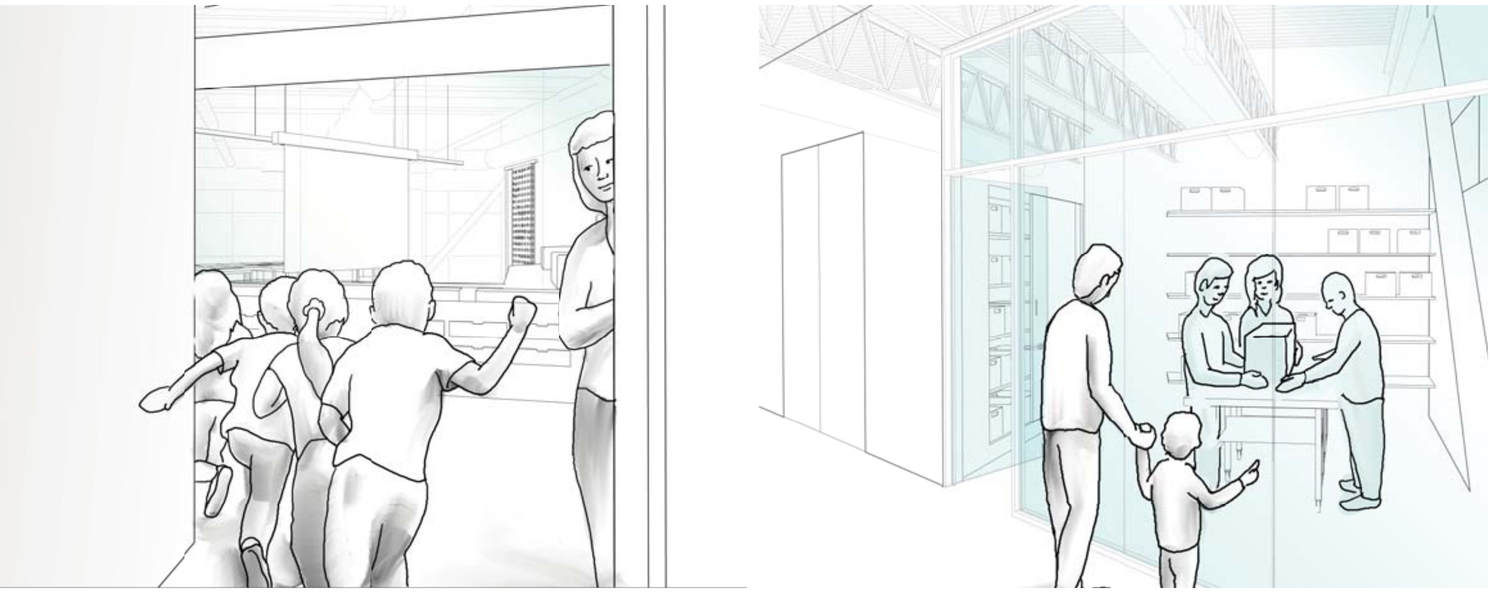


COURTESY OF IDEO

This early Education Center model by IDEO includes arena seating and modular workstations.

CHM has a critical role to play in ongoing dialogues about these contemporary "disruptions." As a museum, we also have an important opportunity free of the typical constraints of "formal" education, we can take risks that most schools cannot—bridging disciplinary boundaries, for example, and experimenting with new modes of teaching and learning without worrying about standardized test results or hewing to externally imposed curriculum requirements. With these advantages, however, come certain responsibilities. Museum learning is inherently social, open-ended, and intrinsically motivated; often termed "free-choice" learning, it demands that we stay relevant, aware of current events and issues, and able to address the needs of all learners, regardless of age, ability, cultural background, or interest.

To contextualize history effectively, we must also step back a bit and approach the sweeping changes we are all living through with a somewhat critical eye. We must contextualize and interpret these transformations from the



IDEO designs promote a dynamic entry to the Education Center from *Make Software* and a research lab that allows visitors a behind-the-scenes look at teaching and learning in the Museum.

COURTESY OF IDEO

perspective of what has come before and what we might be heading toward, and help others do the same. Additionally, as technology becomes more deeply embedded in our lives, it becomes increasingly important for CHM to contribute to the creation of a computationally literate global society.

Computational literacy is just beginning to be understood, but we know that it goes beyond simply using computers and even beyond learning to code. Rather, it encompasses skills and concepts that enable critical thinking about the technological tools we have at our disposal and the ability to apply them in truly unique ways to arrive at creative solutions for real-world issues. For these reasons, education researchers and policymakers recommend that history be integrated into science, technology, engineering, and mathematics (STEM) programs to help elucidate the origins and methods of contemporary STEM inquiry and practice, and their roles in the development of cultures.[1] Indeed, CHM itself was founded on this principle, as a resource for engineers to learn about the roots of their profession.

As we move into the next phase of the Museum's development, the Education Center will become a much-needed resource for innovative programs, research, and partnerships that will both broaden our reach and deepen our impact. One of its most exciting features will be the space itself. To benefit from the most up-to-date expertise in learning space design, we engaged the award-winning firm IDEO as a partner to help develop the physical environment. IDEO is known for transforming business, technology, and education through the application of their "design thinking" methodology—a human-centered process that focuses as much on the users of a space as on its structure. Over the course of several weeks last fall, a team of designers immersed themselves in all facets of the Museum, learning about our culture and mission, exploring our realities and constraints, and leading staff and community members in a series of collaborative exercises meant to uncover previously unimagined possibilities. What resulted was a design that utilizes the space in unexpected ways, optimizing flexibility, social interaction, and hands-on learning. Mark Horton/Architecture, with whom we have collaborated on many projects, is in charge of making the IDEO concept a reality, ensuring that the Education Center will be beautiful, forward-thinking, and eye-opening.

It is important to note that we embarked upon this project with the intention to push ourselves out of our comfort zone, emphasizing experimentation and risk-taking, and inviting in new collaborators and receiving unexpected results—in effect, living the innovation process that we explore in our exhibitions and programs. Like the engineers whose work we collect, preserve, and present, we became aware of a need, articulated a possible solution, and are now ready to implement; after opening, we will evaluate, seek feedback, and iterate as needed to meet future challenges. We believe this is an important process to share, as well: early conversations with colleagues in universities, K–12 schools, museums, and tech firms indicated that we could provide a great service by publicly sharing our experience. Building on their enthusiasm, we hired Scott Burg, senior researcher at San Francisco–based consulting firm Rockman et al., to document every phase of the process. Burg will measure the outcomes against our own internal goals and publish the results, allowing us to learn from our experiments and providing valuable insights for others who are interested in how learning happens in a major educational institution.

On every level, the Education Center is poised to affirm the Museum's position as a thought leader on issues and practices related to computing history and the ways in which we learn with and about technology in our increasingly connected world. As we are fond of saying, we envision the Education Center as a new way to bring the world into CHM and, through cutting-edge technologies and expanded global relationships, to bring CHM out to the world beyond our walls. We are excited for this next important step and look forward to the new opportunities it will afford for the Museum and our communities in Silicon Valley and beyond. ○

About Education at CHM:
Education enables people to make personal connections with the history of computing, broadening their understanding of how technology is transforming our world. Through innovative programming, research, and a dynamic interactive space, Education at CHM allows visitors to dive deeply into the processes and outcomes of technological innovation and provides opportunities for educators and scholars to develop, test, and assess new ways of teaching about these ideas. Education serves our diverse community, including K–college students and teachers, families, global business leaders, and young entrepreneurs, to facilitate new experiences and insights at the intersection of technology and learning.

[1] See "Chapter 6: Science Content Standards" in *National Science Education Standards* (Washington, DC: The National Academic Press, 1996), nap.edu/read/4962/chapter/8 and American Association for the Advancement of Science, *Benchmarks for Science Literacy* (New York: Oxford University Press, 1994), project2061.org/publications/bsl/.

INTERACTIVE WORKSHOPS OFFER HANDS-ON LEARNING

BY STEPHANIE CORRIGAN
MANAGER OF SCHOOL & TEACHER PROGRAMS

What might autonomous vehicles look like in 2040? Can a computer tell you if someone was in your room? How are programming languages like other forms of communication? These are just some of the questions explored during hands-on workshops at CHM. Since the launch of *Revolution* in 2011, we've offered interactive workshops to school groups. In 2016 the Education team developed a new slate of offerings, broadening workshop themes and activities to include CHM's newest exhibition, *Make Software: Change the World!*, and a range of important computing concepts. These new workshops expand options for school groups and make it possible for families and non-school groups to participate as well.

Each workshop emphasizes critical thinking and incorporates the engineering design process and collaborative problem solving into its activities. The programs also highlight how an understanding of computer history can help us prepare for the future. In every workshop, participants explore the Museum's historic artifacts and work in groups to complete hands-on challenges.

Each workshop also has a different theme. One encourages students to imagine and design computers of the future. Another explores language as code, with computer programming languages as just one of many forms of code that people use to communicate. Still others use Raspberry Pi computers to explore the power of software and to control different input and output devices.

School workshops are available for students in grades 3–12 and are a great option for classes looking for an interactive Museum experience. Workshops are also now offered for families on select weekends throughout the year and can be reserved by visiting the Museum's website. ○


TECHNOLOGY
Painting the Picture
We think of MRI "machines" as hardware. Yet much of their power lies in their software, which controls the magnetic and radio-frequency pulses, collects and interprets the resulting signals, and then transforms this data into images.
Depending on the MRI settings, images can highlight fat, fluid, air, bone, or soft tissues in the patient.
FLUID (BLOOD)
FAT
MRI

Computers help us design safer cars, diagnose disease, and battle Orcs. They manage our business by day and entertain us at night. Smartphones can hail a cab, send a text, or play a tune. All thanks to software. Software enables computers, tablets, even appliances to touch and transform nearly every aspect of daily life. Our devices brim with extraordinary potential. Software unlocks that potential.

On January 28, 2017, the Computer History Museum (CHM) opened its major exhibition on software, *Make Software: Change the World!* Enjoy this behind-the-scenes tour of *Make Software* with feature articles by Center for Software History Director David C. Brock and Vice President of Collections and Exhibitions Kirsten Tashev.

SOFT

BY DAVID C. BROCK
DIRECTOR, CENTER FOR SOFTWARE HISTORY

The Museum's ambitious new exhibition, *Make Software: Change the World!,* opened to the world at the start of 2017, but readers of *Core* were first introduced to its themes and its stories in 2013. In an essay in that issue, Senior Curator Dag Spicer addressed "Why Software History Matters." In short, Spicer argues that software history matters because software itself matters—it is inextricably bound to computing devices, it touches and shapes our lives truly from life to death and is a human creation filled with promise and peril. Software has a rich history, opening up and answering important questions about how computing has shaped our world.

There are as many ways to approach software history as there are ways in which our contemporary world and lives are entangled with it. But one revealing way to distill the story of software history is a simple, two-word phrase: *Software, Everywhere*. It's catchy and easy to remember, but what does it really mean?

To simply type the word "software" into the search box of Google News is a great place to start. Here, a web browser (software) relays the query (using elements of the operating system software and an ISP's server software) to Google's global network of data centers and their server software. The results from Google's software scouring of online news sources connected to the word "software," are relayed back to the browser (through software), which the browser and other software render as a collection of news articles on the screen.

Visualization of MRI data by software allows doctors to look inside the bodies of their patients, while Photoshop serves as a new medium for visual artists to express their creativity.

Where does the top news on "software" take you? *It takes you literally everywhere, geographically and culturally*: An "Australian cloud technology company" raises money from a New York City private equity firm. MIT researchers make new code for 3-D printing with mixed materials. A Russian firm takes a leap forward in facial recognition software, amid worries about its use. Professors at Imperial College London ponder how to best teach contemporary software development. Facebook aims to take on Slack for business communication and collaboration. Microsoft and Salesforce crow about their use of artificial intelligence in business software. Critics take aim at software-as-a-service as a panacea. Airport management software made in Germany and used everywhere from Bahrain to Singapore, from Prague to Sydney, and from Athens to Zurich, finally arrives in the United States. The "Auto industry heads into fierce software race." New software is released for comparing the performance of other software that drives scientific instruments at the heart of life sciences and synthetic biology research. Silicon Valley investors are now paying particular attention to the "game engines" at the heart of video and computer games, which is a $100 billion global market. China is hailed as the new center of gravity for open source software.

RON LEVINE VIA GETTY IMAGES / *ICE LIKE FIRE* © 2015 THE FIFTH ORDER/JEFF HUANG. COMMISSIONED BY HARPER COLLINS. PHOTO COURTESY OF JEFF HUANG

WARE EVERY WHERE

Because Africa is inadequately covered by the news media, type “software Africa” into Google News: the *Wall Street Journal* reports that the “Tech Talent War Moves to Africa,” as US firms seek software development workers in Africa. A South African startup uses an Android mobile app to diagnose hearing loss. Small- and medium-size businesses in East Africa increasingly are using legal copies of software, as losses mount from malware embedded in illegal copies. “Africa Code Week” is underway, with coding instruction experiences for youth across the continent, sponsored by German software giant SAP.

Searches for news about “software Arctic” and “software Antarctic” even return results. Facebook’s data center above the Arctic Circle takes advantage of the ambient temperatures for cooling its servers running Facebook’s services (software). Researchers are now using software, instead of fieldwork, to count Antarctica’s penguins.

This simple experiment reveals the extent to which software is now everywhere, geographically and culturally. People’s creation and use of software is now, directly or indirectly, an integral part of education, work, politics, entertainment, discovery, invention, and creativity. The story of “Software, Everywhere” is nothing less than the story of computing itself. Software is exactly that which computers do—no more, no less. As the technical and economic dynamic of Moore’s Law has dramatically reduced the cost of digital computing across the past half century, people have incorporated digital computers—in the form of microprocessors and microcontrollers, most often embedded in other products—into all aspects of society. Billions of these silicon computers are manufactured each and every year with only one purpose: to run software. The suffusion of silicon electronics and digital computing into our lives is exactly the process through which, as Marc Andreessen has said, “software is eating the world.”

Make Software: Change the World! draws visitors in with compelling examples of how software impacts their lives and those of other people across the globe—from mobile banking by text messaging in Africa to the alternative reality of *World of Warcraft*, in which millions of players engage worldwide; from simulation software that helps engineers make cars safer to imaging software that allows doctors to peer inside of our bodies; and from Wikipedia as a collective store of people’s knowledge to Photoshop as a powerful tool for creative visual works of incredible variety.

Crash simulation software helps engineers to design safer cars. To validate these simulations, cars are fixed with sensors before test crashes.

GAUTIER STEPHANE / ALAMY STOCK PHOTO

BY KIRSTEN TASHEV
VICE PRESIDENT OF
COLLECTIONS & EXHIBITIONS

MAKIN

Make Software: Change the World! is a 6,000-square-foot exhibition, designed by firm Van Sickle & Rolleri, that explores the history, impact, and technology of software through seven game-changing applications: Photoshop, MP3, MRI, Car Crash Simulation, Wikipedia, Texting, and *World of Warcraft.*

G

MAKE SOFTWARE

An exhibition about the history of software. On first blush, it sounds like one of the hardest exhibition topics of all time. Many years ago, at a museum conference, I attended a session called “Exhibiting Challenging Topics.” The idea was that the audience would propose a list of difficult topics and the group of professionals would brainstorm solutions. People called out “the Holocaust” and “racism” and “photosynthesis.” I lifted my hand and said “the history of software,” to which there was an audible groan. Needless to say, it wasn’t chosen as one of the “difficult” topics to workshop.

People tend to think museum exhibitions are about artifacts and physical objects, but there are plenty of museums without objects, like science centers. Ultimately museums are about storytelling and engaging visitors with different expertise and learning styles. I never really felt that an exhibition on the history of software was impossible. After all, artifacts are just one trick in the museum exhibition developer’s toolkit. The key is choosing stories that ignite visitors’ imaginations and creating an exhibition with multiple entry points—including text, images, media, interactive, and objects—if possible.

Fast forward to January 2017. CHM opens a major exhibition about software: *Make Software: Change the World!* How did this exhibition happen?

For years, the Museum has collected hardware and software. While the Museum's permanent exhibition, *Revolution: The First 2000 Years of Computing,* features many software stories, including a software theater, for the most part, the 1,200 artifacts showcased in the exhibition carry *Revolution*'s story. And, for those of us in Silicon Valley at least, artifacts = hardware. Additionally, while developing the storylines for *Revolution*, the interpretive team found that the Museum's holdings were, for the most part, from the technology creator's perspective—who we call "makers." In attempting to show the impact of technology for the visitor, the team struggled to find "user" stories in the collection. Out of this came a commitment to collect a more rounded story about computing of both makers *and* users. In addition, an evaluation of *Revolution* after it opened revealed that our visitors wanted to learn more about how technology impacts their lives. We call this the "impact story." For these reasons, combined with the Museum's larger initiative to explore the history of software, we decided to shine a special light on software and create a groundbreaking exhibition.

During this same time, the Museum's educational programming was taking off. The Education team developed compelling STEM-inspired programs for students and families, including Design_Code_Build, a series of workshops for middle school students to see science, technology, engineering, and mathematics as an exciting adventure in which they can participate. The new software exhibition, *Make Software: Change the World!* is a natural partner to the Museum's educational programming, featuring storylines and hands-on interactives that would appeal to middle school students, families, and tech enthusiasts alike.

The Museum's interpretive team was challenged to come up with an exhibition that would highlight the impact, technology, and history of software in five to eight case studies (not covered in *Revolution*) demonstrating the breadth and depth of software's impact on people's lives. In

The exhibition's unique circular design, conceived by exhibit designer Dennis Van Sickle, encourages exploration while also creating unexpected nooks that house multimedia interactives and provide further opportunities for learning and discovery.

addition, the exhibition would appeal to visitors of all ages and feature interactive and multimedia technology.

Before choosing case studies or software to feature in the exhibition, the team developed goals and key messages. The goals helped the team select seven software applications to feature out of the hundreds of options, while the key messages guided the storytelling and exhibition techniques. The goals of *Make Software: Change the World!* are to explore the impact of software on people's lives, to illuminate the relationship between software makers and users, to demystify how software is made, and to reveal the history of software. The key messages are what we want visitors to conclude from visiting the exhibition: software has had a huge impact on the world, it has deep historical roots, creating software is a complex process, and it is only limited by human imagination.

People often ask, how do we decide what goes into an exhibition? The answer is one part analytical and the other part gut. With the above goals, key messages, and audiences in mind, the team made a list of software stories, organized them into categories, including software complexity and industry types, debated impact on society, and explored available assets. Making an exhibition is not just about goals, messages, didactic information, and storytelling, so we also rated our story

INTERACTING WITH SOFTWARE

BY EMILY ROUTMAN
INTERPRETIVE PLANNER

Each story in *Make Software: Change the World!* includes a custom computer-based interactive experience. Computer interactives, also known as multimedia programs, can engage visitors in ways not possible with simpler media. *Make Software*'s multimedia programs put visitors in the role of software makers and users, giving them the ability to:

- program a digital frog to catch bugs in a lily pond,
- pinpoint injuries on patients' MRI images,
- compare crash simulations with real car crash tests,
- edit themselves into a scene with a famous person using Photoshop.

The multimedia programs are built around authentic components inherent in the software stories, including real MRIs and auto-industry crash test simulation models. The Photoshop interactive runs the famously complicated software within an easy-to-use interface. In some cases, the programs are part of the story. For example, Northwestern University professor Michael Horn created the "Frog Pond" interactive, located in the exhibition's Stata Family Software Lab, as part of his research into making programming accessible to kids. CHM was also the first organization to work with Google's Blockly software, a highly intuitive programming interface, which has since taken off as a major software initiative with broad applications in education.

candidates for wonder, theatricality, humor, and playfulness. We talked to visitors, board members, donors, and friends to get their input. We set the following criteria: software-based breakthroughs from the 1980s onward, primarily to extend the storyline beyond *Revolution*, which concludes with a gallery about networking and the web; impact on a large scale but also affecting the average person; diverse examples across industries; and dramatic stories with emotional connections.

At the end of the day, we chose seven application stories that represented different types of software that had a wide variety of impact on the world and organized them into three big-picture impact groupings:

Perception & Reality:
Photoshop and MP3

Life & Death:
MRI and Car Crash Simulation

Knowledge & Belonging:
Wikipedia, Texting, and *World of Warcraft*

To create consistency across the diverse application stories, we decided on three lenses through which we would explore each story: History, Technology, and Impact. Each story would feature graphics, object displays, a documentary film about makers and users, and a hands-on interactive for a direct experience with the software. Some fun examples include, creating a selfie with a famous person using Photoshop, listening to songs and guessing the audio format, diagnosing a patient by studying MRIs, exploring car crash simulations from different decades, and playing a *Jeopardy*-style game to learn about Wikipedia.

CAPTURING *MAKE SOFTWARE* ON SCREEN

BY JON PLUTTE
DIRECTOR OF MEDIA

It was a September evening not that long ago, and I sat at the Castle Pub in Notting Hill, London, with curator Marc Weber. As we drank our ales and ate fish and chips, we talked about our European video interview trip.

We had already done several productive interviews in London: Jimmy Wales, co-founder of Wikipedia; texting scholar Caroline Tagg; and many Wikipedia editors at the British Library. We had just made our way to Nottingham to interview Sir Peter Mansfield, winner of a Nobel Prize for his part in the invention of MRI. In a couple of days we would fly to Bonn, Germany, then drive to Ilmenau to interview Karlheinz Brandenburg, inventor of the MP3. After my departure, Marc would fly to Kenya to interview bankers, technologists, and Maasai tribesmen about Kenya's groundbreaking text-based banking system, M-Pesa.

What Marc and I talked about was the breadth and quality of these interviews; how the people we met had really brought their stories to life; how interviewing people who are passionate about their work is inspiring to us as filmmakers, curators, and storytellers; and how we hoped it would inspire visitors to this new exhibition.

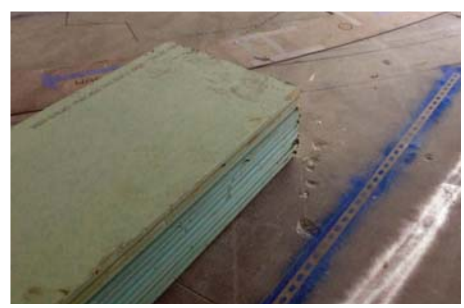
As you watch the movies in *Make Software: Change the World!*, read the text on the graphic panels, and look at the images, remember that this exhibition is current history. Many of the creators are still alive, captured in the films throughout the exhibition. I have no doubt that the exhibition will spark passionate and interesting discourse, not just with scholars, but also with the actual creators of the software, and with you.

Left to right: VP of Education Lauren Silver, CEO John Hollar, and VP of Collections and Exhibitions Kirsten Tashev commemorate the official start of construction on *Make Software*, June 29, 2016.

In addition to the seven application stories, we wanted to provide visitors an opportunity to explore software as a concept, outside of the specific application story. The idea for a software exploration lab came from an earlier exhibit on computer chess. This exhibit, which explored the history of computer chess, included a few analog chessboards as an afterthought. We were surprised to find visitors playing chess in the exhibit for hours. It underscored the power of interactivity and the need for visitors to internalize the story through play. At the heart of *Make Software: Change the World!* is the Stata Family Software Lab. In the lab, visitors explore programming basics through low-tech and touchscreen interactives using visual programming languages and blocks to internalize software techniques.

Also included in the lab is a theater, where a documentary film made by the Museum follows a Silicon Valley company making a software product over the course of two years. We wanted to demystify how software is made and to demonstrate to our audiences that software teams are a diverse mix of professionals and not just coders. We plan to add more documentaries from different companies over time.

Make Software: Change the World! introduces a new chapter in the Museum's quest to tell the amazing story of computing and to reach a broader audience. It is also a call to action. We hope that visitors will see themselves in this dynamic relationship between makers and users that is changing the world. ○



Members of CHM's dedicated interpretive team at the entrance to *Make Software,* January 2017. Left to right: Jon Plutte, Max Plutte, German Mosquera, Marc Weber, Kirsten Tashev, John Hollar, Dag Spicer, Chris Garcia, Jenny De La Cruz, Vinh Quach, Ton Luong, and Ganna Boyko.

PERCEPTION & REALITY

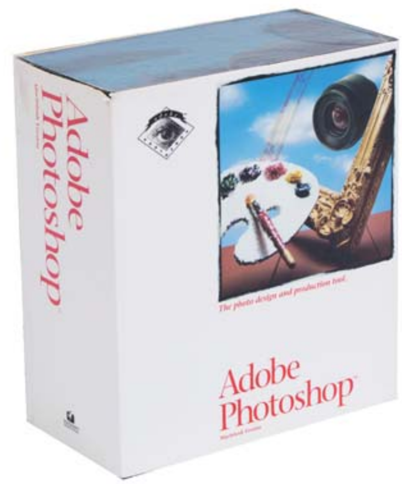
PHOTOSHOP

Picture Perfect?
That gorgeous fashion model on the billboard? Not *quite* so gorgeous in person. The extraordinary science photo of our galaxy? The original was less dramatic. That Facebook picture of your brother-in-law golfing with the President? They're not *actually* fairway buddies.

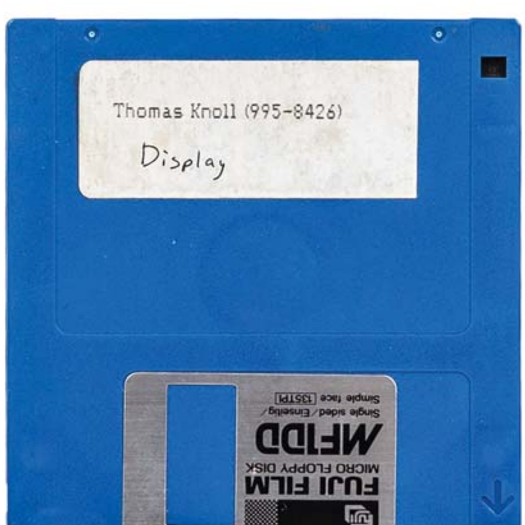
From fashion spreads and films to product packaging and news images, Photoshop helped transform our view of the world—and our trust in what we see.

CURATED BY DAG SPICER
SENIOR CURATOR

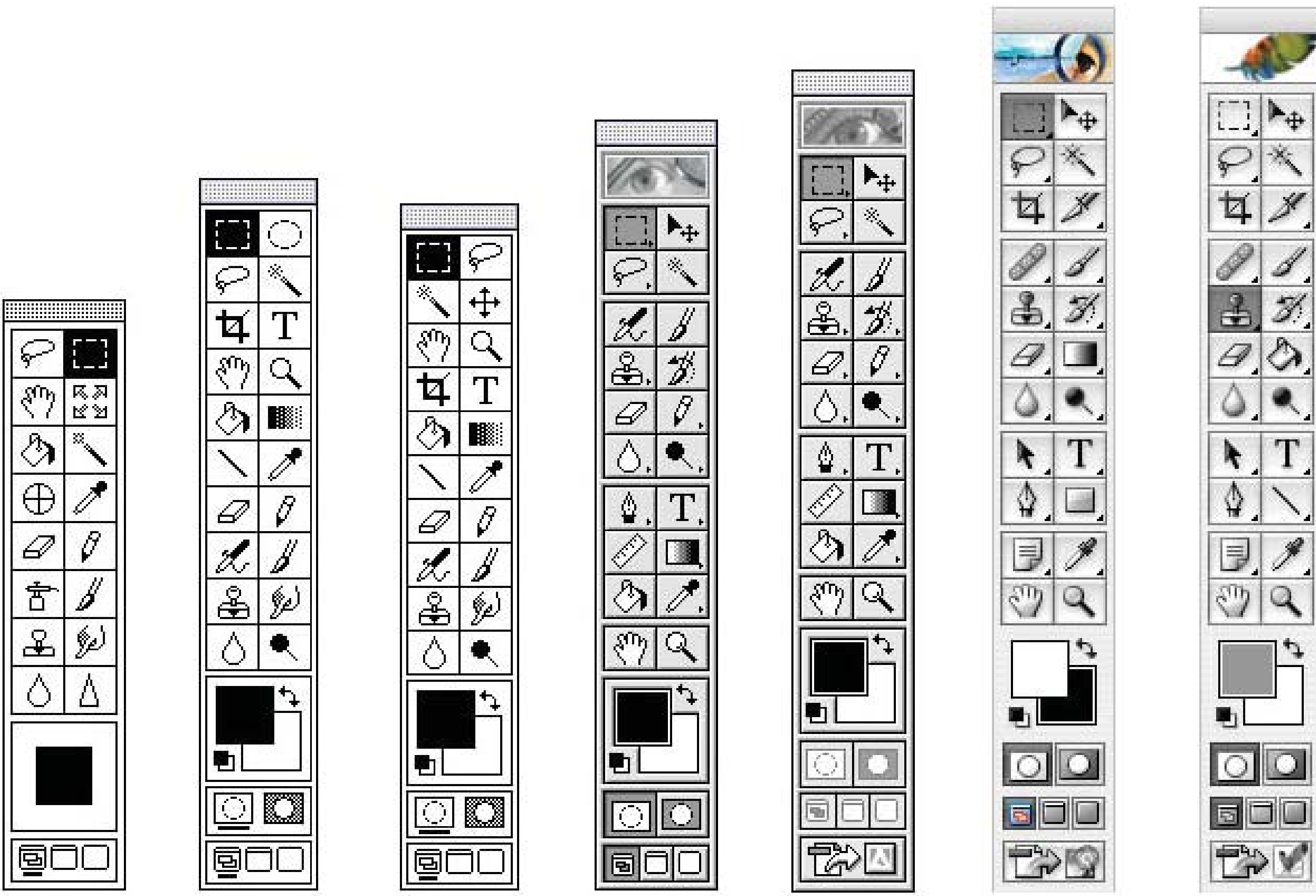
Adobe Photoshop 1.0, 1990
The first version of Photoshop was only available for Apple Macintosh computers. Photoshop was a major improvement over renting custom image-editing computers, which could cost up to $300 an hour.



Thomas (top) and John (bottom) Knoll



Display, ca. 1987
Display was the name of the image-editing program developed by Thomas and John Knoll before they renamed it Photoshop in 1988.



1987 2.5 3.0 5.0 5.5 7.0 CS

Evolution of the Photoshop toolbar
With each new version, Photoshop adds new features to its creative toolkit, underscoring the evolution of the product itself. Key milestones include: Photoshop adapted for Windows (2.5), layers feature added (3.0), history palette added (5.0), Photoshop optimized for the web (5.5), and healing brush added (7.0).

July 1917 Columbia Records Catalog
Before online music stores, record companies published catalogs with their upcoming offerings. Columbia Records released catalogs on the 20th of each month.

PERCEPTION & REALITY

MP3

You Call the Tune

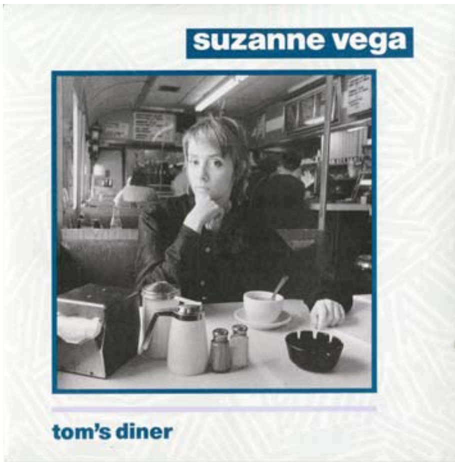
Hear an intriguing new song? With a tap or click it's yours—thanks partly to MP3s.

By creating smaller audio files, MP3s helped make music instantly available and easily shared. You could download tunes from the internet and fit your collection on a pocket-size player.

MP3s transformed music distribution, creating industry winners and losers. But some questioned if we were sacrificing quality for convenience.

CURATED BY MARC WEBER
CURATORIAL DIRECTOR,
INTERNET HISTORY PROGRAM

Apple iMac "Rip. Mix. Burn." advertisement, 2001
The 2001 Apple iMac featured iTunes, Apple's new "jukebox" software. Users could build and manage their own music libraries and create their own CDs with the built-in CD-RW drive.



Album cover, "Tom's Diner," by Suzanne Vega

Audio team in 1987 (Brandenburg with headphones)
While refining his MP3 code, Karlheinz Brandenburg heard Suzanne Vega's hit "Tom's Diner" playing on the radio. He realized that this a cappella song would be nearly impossible to compress successfully. *Nearly.*

Pono Player, 2015

Tower Records, Portland, Oregon, 2006
MP3s gained popularity in the late 1990s as they spread over the growing internet. Digital music eventually put most brick-and-mortar music stores out of business.

Apple iPod (5GB), 2001

LIFE & DEATH

MRI

Seeing Inside

No knives. No blood. No sticking out your tongue and saying, "Ahhhhh." Magnetic resonance imaging (MRI) lets doctors look inside you safely and painlessly.

It's a uniquely detailed diagnostic tool, sensitive enough to detect a ripple of fluid in the brain or the minute narrowing of a blood vessel—without using X-rays, which can be harmful.

MRI technology blends physics, engineering, mathematics, biology, and medicine . . . all coordinated by software.

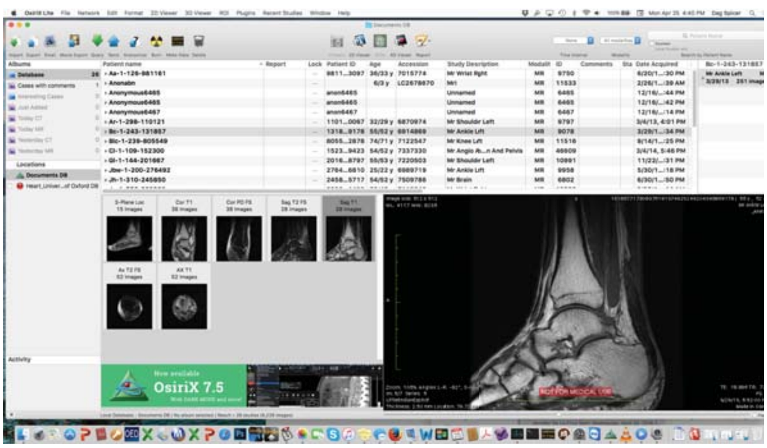
CURATED BY DAG SPICER
SENIOR CURATOR

MRI whole body scan

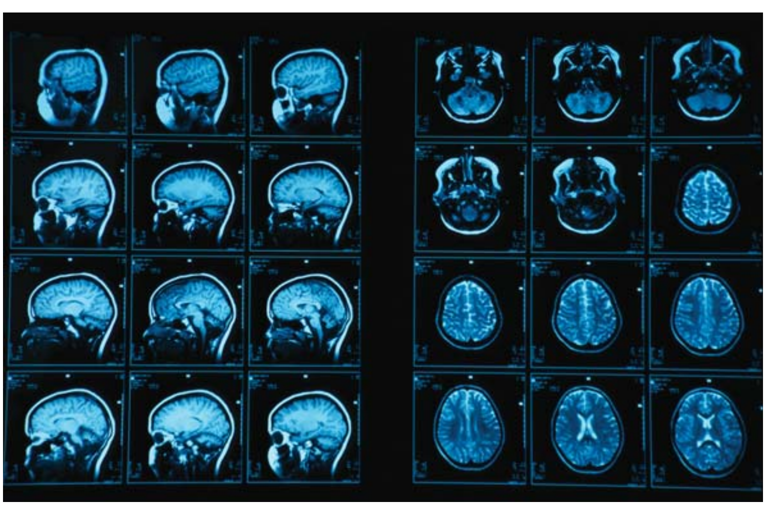
For centuries human anatomy remained a mystery. Public dissections and experiments were common, but yielded limited knowledge. Today, noninvasive medical imaging techniques, like MRI, enable doctors to learn what's happening inside our bodies without cutting into them.

SIMON FRASER/SCIENCE PHOTO LIBRARY

Modern MRI machine



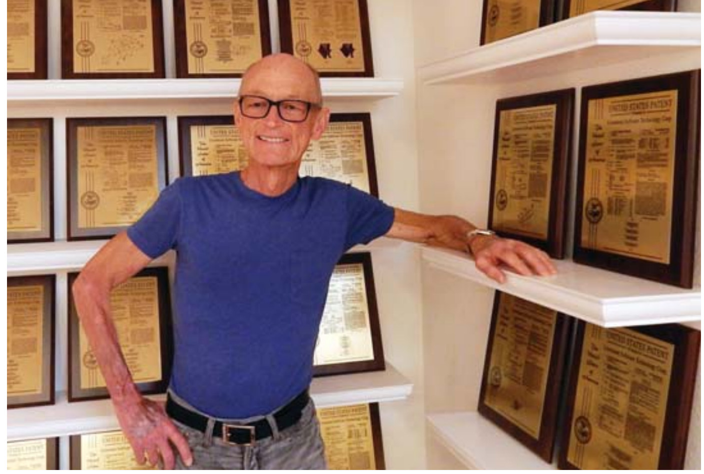
OsiriX DICOM image viewer



Brain MRIs
MRI captures 3-D pictures of an area, like your brain, by imaging different layers, called *anatomical planes*. The three basic anatomical planes are axial (top to bottom), coronal (front to back), and sagittal (left to right).

Sir Peter Mansfield, 2003 Nobel Prize (shared)
MRI evolved over decades, beginning in 1937 with Isidor Rabi's discovery of nuclear magnetic resonance. In the 1970s, Paul Lauterbur and Peter Mansfield independently suggested applying precise variations in a *second*, "gradient," magnetic field to pinpoint resonating molecules.

Isidor Isaac Rabi, 1944 Nobel Prize



John Hallquist, 2014
John Hallquist is the creator of the earliest crash test software, LS-DYNA (originally called DYNA3D). He left Lawrence Livermore National Laboratory in 1987 to start his own company, Livermore Software Technology Corporation.

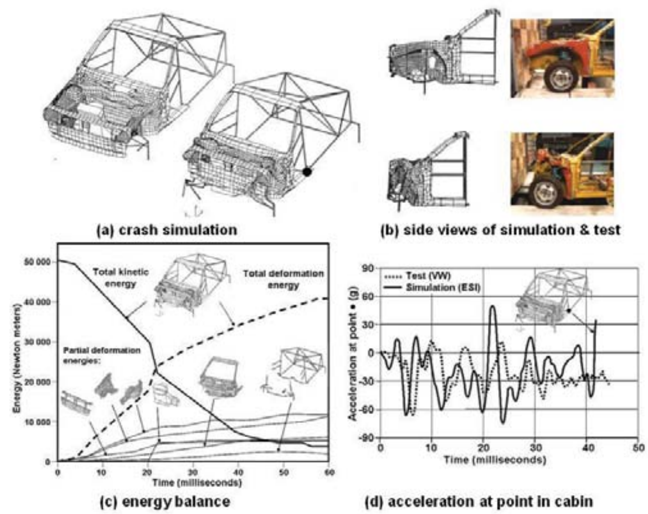
LIFE & DEATH

CAR CRASH SIMULATION

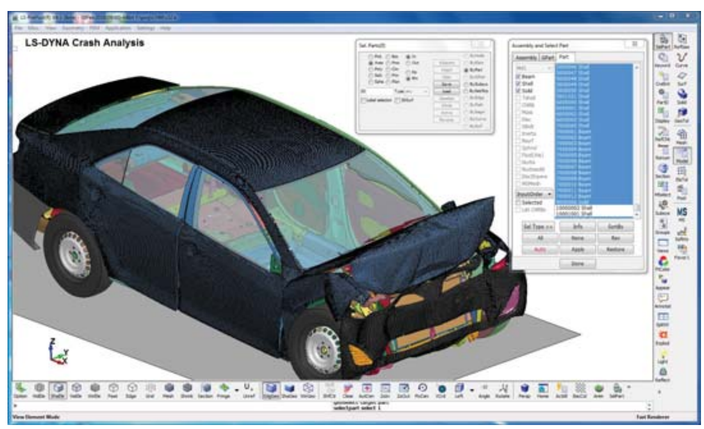
Simulating Safety
Would you volunteer to drive into a brick wall? Probably not, which is why computer simulations are crucial to auto safety.

Software lets engineers run crash tests inside computers rather than on roads. It also allows them to compare the performance of different designs early in the process while cars are still on the drawing board, saving money *and* injuries.

CURATED BY DAG SPICER
SENIOR CURATOR

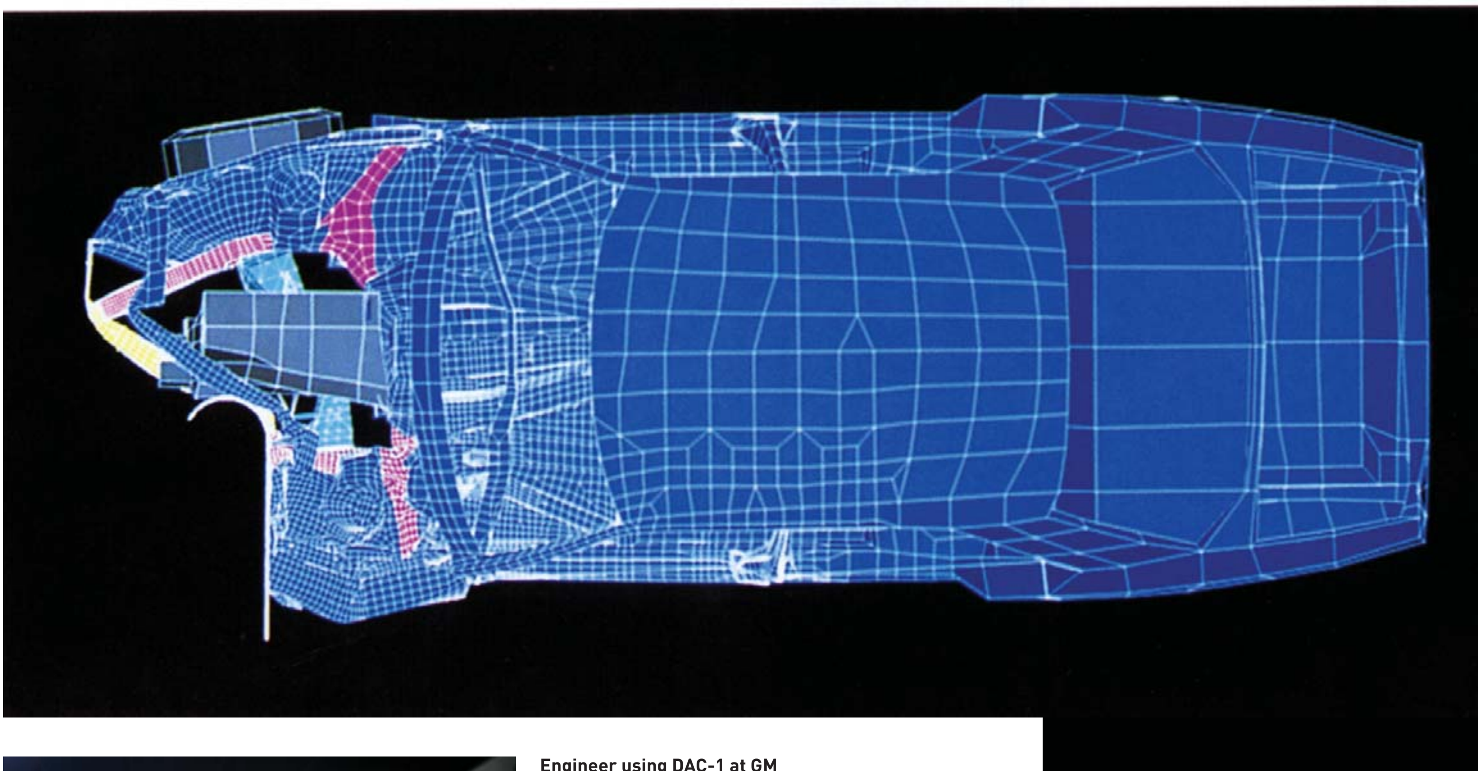


Comparison of simulated and physical crash test results of VW Polo simulation, 1986



Car crash simulation using LS-DYNA software, 2016
This virtual car simulation, shown in the program LS-DYNA, shows the finite element method "mesh" covering the car. Each point in the mesh represents a series of calculations.

Real and simulated crash test. Simulation performed on Cray supercomputer.



Engineer using DAC-1 at GM Research Laboratories, 1966
In 1964 General Motors and IBM announced the DAC-1 computer-aided design system for cars. The system acted as an electronic sketchpad and controlled a milling machine to produce a physical model.

CRASH TEST: CRAY RESEARCH INC. / COURTESY OF GENERAL MOTORS / DAC-1 COURTESY OF GENERAL MOTORS

Wikimedia project lapel pins, 2015

KNOWLEDGE & BELONGING

WIKIPEDIA

The Answer Place
Wikipedia needs no introduction, which in itself is a kind of introduction, acknowledging its global role as our go-to information source.

The collection of online encyclopedias—with editions in more than 200 major languages—is the internet's sixth most visited site, drawing more eyeballs than eBay, Amazon, or Twitter. It's the only top website that's noncommercial, open source, and, most important, created by users . . . and edited by anyone.

Jimmy Wales, December 1, 2006

CURATED BY MARC WEBER
CURATORIAL DIRECTOR, INTERNET HISTORY PROGRAM

Wiki-Wiki airport bus, January 25, 2007
Wiki inventor Ward Cunningham learned the Hawaiian word for "quickly"—wiki—when he took the airport bus in Honolulu. It struck him as the perfect name for his new, instant collaboration system: WikiWikiWeb.

Five pillars of Wikipedia
When Jimmy Wales and Sanger launched Wikipedia as a way to quickly crowd-source rough articles for Nupedia, Sanger came up with core principles that would later be formalized as the "five pillars" of Wikipedia.

Wikipedia University T-shirt, ca. 2016

Barnstar
Within the community of Wikipedia editors, barnstars serve as commendations for important service. They echo traditional iron stars on early American barns built—like Wikipedia—with community labor.

KNOWLEDGE & BELONGING

TEXTING

GSM meeting endorsing SMS proposal, Oslo, Norway, 1985

The project to agree on a Europe-wide digital mobile phone standard, GSM, involved telephone companies from around Europe meeting over a number of years. The SMS working group was one small part of that gigantic effort.

The Triumph of Texting

Texting is as flexible as email, as immediate as a call, and as close as the computer in your pocket. Those features make it popular worldwide.

In the developing world, however, texting (Short Message Service, or SMS) plays an additional role as an "alternate internet." Three billion largely poor or rural users depend on SMS to transfer money, find jobs, connect to social networks, and more.

CURATED BY MARC WEBER
CURATORIAL DIRECTOR, INTERNET HISTORY PROGRAM

Safaricom's M-Pesa agent in Nairobi, Kenya, August 17, 2015

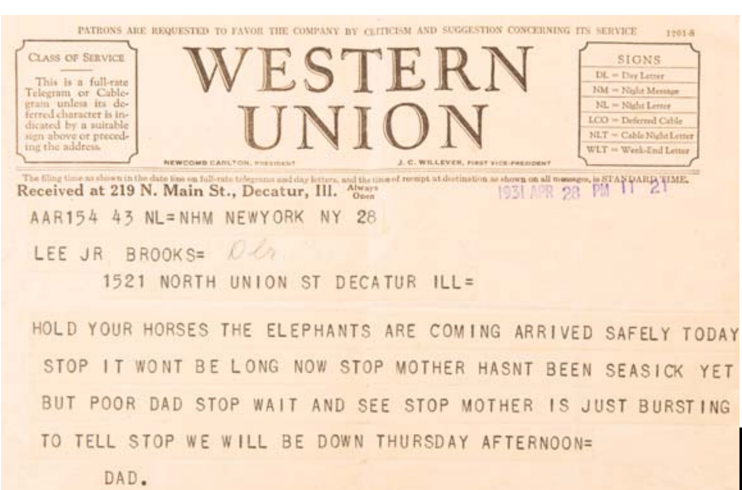
Ericsson NH97 NMT cell phone, Sweden, early 1990s

Motorola digital phone, early 1990s

T-Mobile myTouch 875

Blackberry 7230, 2003

Message in Arabic Chat Alphabet, "How are you doing with your studies?" Early phones supported only the Latin alphabet. So, speakers of non-Latin languages, like Arabic, got creative by mixing numbers and Latin letters.



PATRONS ARE REQUESTED TO FAVOR THE COMPANY BY CRITICISM AND SUGGESTION CONCERNING ITS SERVICE

CLASS OF SERVICE

This is a full-rate Telegram or Cablegram unless its deferred character is indicated by a suitable sign above or preceding the address.

WESTERN UNION

NEWCOMB CARLTON, PRESIDENT J. C. WILLEVER, FIRST VICE-PRESIDENT

SIGNS
DL = Day Letter
NM = Night Message
NL = Night Letter
LCO = Deferred Cable
NLT = Cable Night Letter
WLT = Week-End Letter

Received at 219 N. Main St., Decatur, Ill. Always Open 1931 APR 28 PM 11 21

AAR154 43 NL=NHM NEWYORK NY 28

LEE JR BROOKS=

1521 NORTH UNION ST DECATUR ILL=

HOLD YOUR HORSES THE ELEPHANTS ARE COMING ARRIVED SAFELY TODAY STOP IT WONT BE LONG NOW STOP MOTHER HASNT BEEN SEASICK YET BUT POOR DAD STOP WAIT AND SEE STOP MOTHER IS JUST BURSTING TO TELL STOP WE WILL BE DOWN THURSDAY AFTERNOON=

DAD.

Western Union telegram, April 28, 1931 Telegrams were expensive, and paid by the word. This encouraged a terse, "telegraphic" style. With codebooks, like *The Adams*, you could send a whole phrase for the price of a word.

KNOWLEDGE & BELONGING

WORLD OF WARCRAFT

A Place to Play
Every day, people around the globe head to the same place to meet friends, test their mettle, and have fun. And it's a place that doesn't even exist.

World of Warcraft's virtual realm boasts more people than Sweden. It earns $2 billion annually in subscriptions, outperforming many small nations. And this extraordinarily compelling, popular, profitable world is entirely a creation of software code.

CURATED BY CHRIS GARCIA
CURATOR

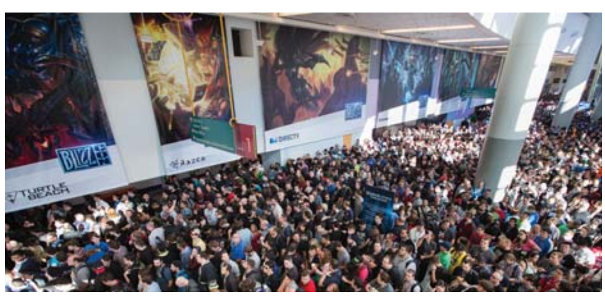
Statue of Thrall, ca. 2002
Thrall, orc leader of the chaotic Horde and wielder of "Doomhammer," is one of the most recognizable characters in *World of Warcraft*. He first appeared in the 2002 game *Warcraft III: Reign of Chaos*.

Warcraft: Orcs & Humans, 1994

Wedding invitation and custom coins, 2013

"Those Who Couldn't Be Saved," *WoW: Legion*, 2016

Sam "Samwise" Didier,
Senior Art Director, Blizzard
Teams of artists and musicians work behind-the-scenes to create the look, feel, and sound of *World of Warcraft*. Pencil sketches and symphony orchestras blend seamlessly with computer-generated art and digital music.



BlizzCon 2014, Day 1

World of Warcraft **expansions, 2007–2016**
Blizzard's expansions of *World of Warcraft* have allowed the game to remain fresh, advancing the central storyline, introducing new quests, and allowing players to experience new levels.

ORCS & HUMANS AND BLIZZCON: COURTESY OF BLIZZARD ENTERTAINMENT INC. / LEGION: MEDIEVALDRAGON VIA WARCRAFT.BLIZZPLANET.COM, DECEMBER 13, 2015/© BLIZZARD ENTERTAINMENT INC.

STATA FAMILY SOFTWARE LAB

What is Software?

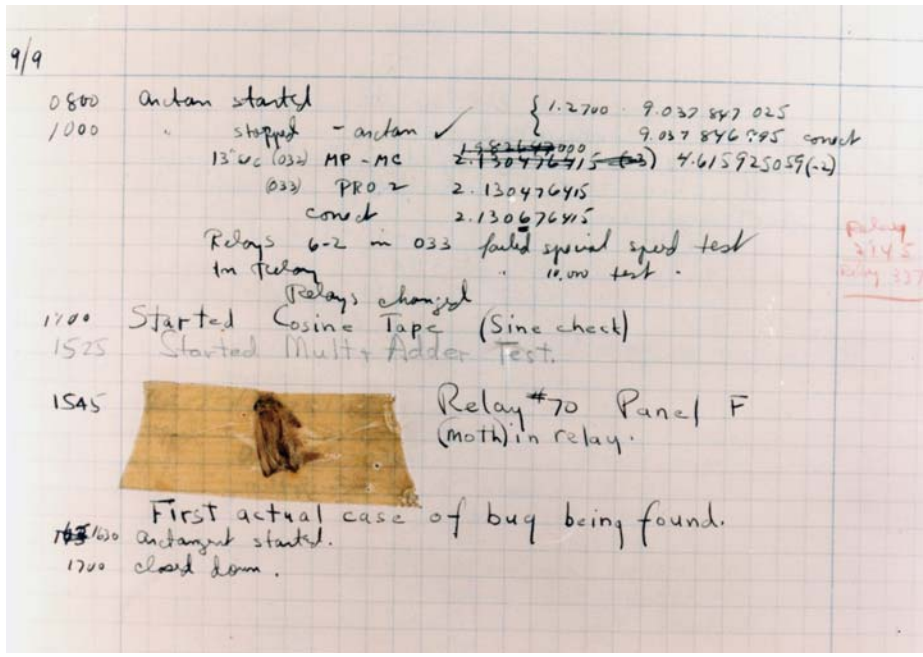
Computers have the *potential* to do wondrous things. But actually doing them? That needs software.

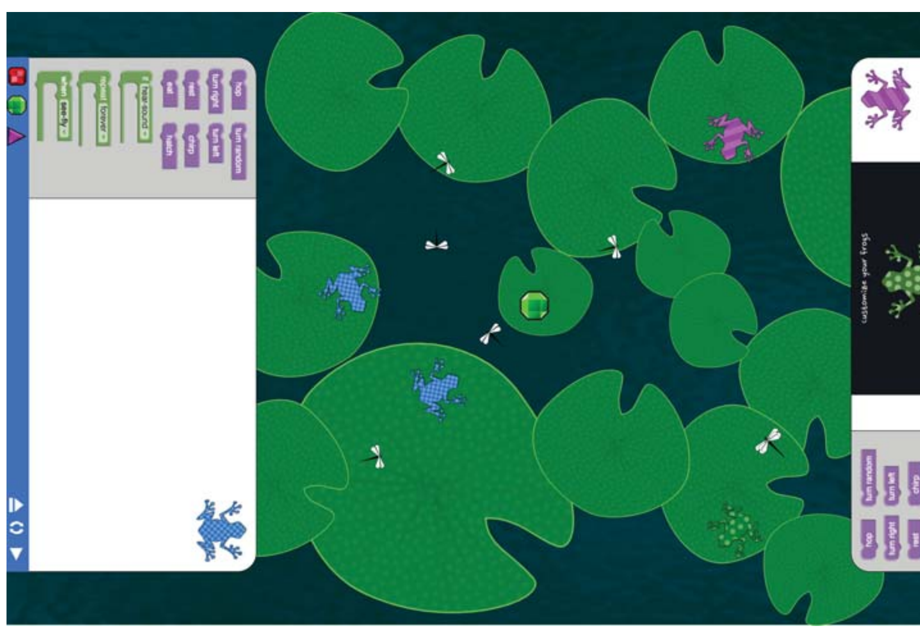
Software transforms general-purpose machines into useful tools, providing instructions that tell them what to do and how to do it. These instructions might be simple or complex, long or short, depending on the task.

Programmers write software in various computer "languages," which use different ways to tell the computer what to do.

Page from Harvard Mark II logbook, September 9, 1947

In 1947 a young programmer named Grace Hopper discovered a moth trapped inside the Harvard Mark II computer. She recorded the error and taped the bug into the computer's logbook, shown here. Software errors have been called "bugs" ever since.



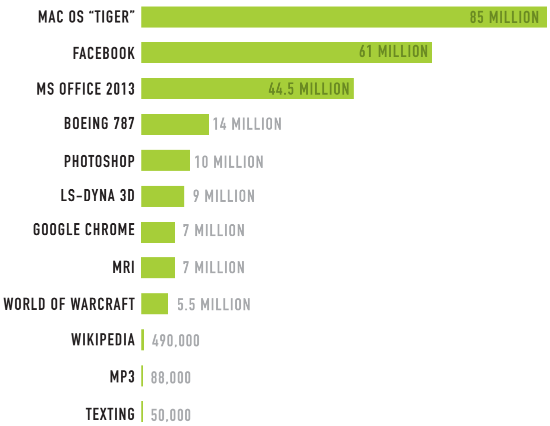


Frog Pond

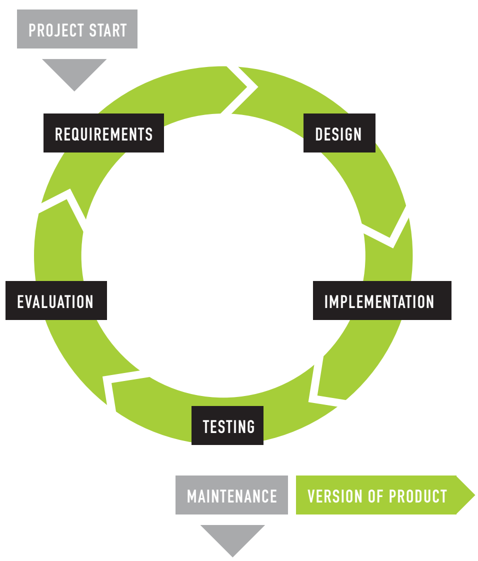
Northwestern University professor Michael Horn created the "Frog Pond" interactive to make programming accessible to kids. CHM was also the first organization to work with Google's Blockly software. Visitors can experience the Frog Pond and Blockly in the Stata Family Software Lab.

LOGBOOK: US NAVY PHOTO

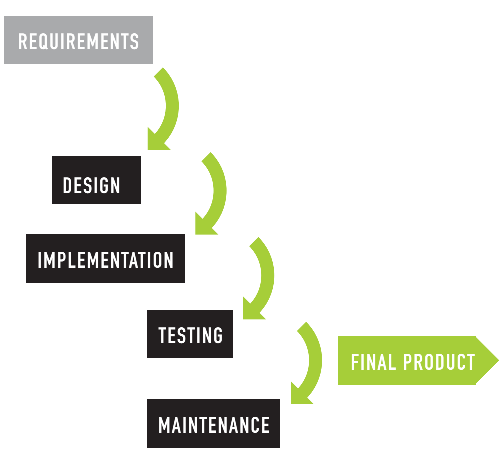
Lines of code visualization



Agile method



Waterfall model



LOGO programming on Apple II, ca. 1980

LOGO: IMAGE MADE BY EMULATION.

The Computer History Museum (CHM) is committed to exploring the forces of change that computing in all its forms has unleashed. The research conducted by the Museum illuminates the transformation of computing in the world, analyzing its history, impact, and future technological, societal, and economic implications. Gain unique insight into computing's transformation with this rich selection of articles.

First, historian and author John Markoff paces us through the Silicon Valley race to put computing in your pocket. Next, Marc Weber, curatorial director of CHM's Internet History Program, explores digital preservation in a case study about the Museum's software initiative, with a special focus on web and networking history. Finally, curator Hansen Hsu reveals the secret history of Objective-C, the programming language that powers nearly all of Apple's major products, from the iPhone to the iPad, but whose origins reside in a small startup called Stepstone.

RESEARCH & INSIGHTS @ CHM

WHEN SILICON VALLEY REALIZED IT COULD PUT COMPUTING IN YOUR POCKET

BY JOHN MARKOFF
AUTHOR & HISTORIAN

Left to right: PalmPilot wooden model, ca. 1995; model of the Dynabook "dynamic book," 2010; and PalmPilot handheld computer, 1996.

IMAGES © MARK RICHARDS

A quarter century ago, two young computer engineers, Tony Fadell and Andy Rubin, worked immediately next to each other at General Magic, a much ballyhooed Apple Computer spinoff, which was advertising itself as the future of computing.

They were each hardware hackers in the best sense of the word. Fadell was obsessed with consumer gadgets and Rubin was an early robotics hobbyist. In 1991, at General Magic, they were instrumental in jumpstarting a shift in Silicon Valley away from the desktop computer to a computer that you could hold in the palm of your hand.

It was a transition that would take almost three decades from the first glimmer that it might be possible to put a powerful computer in your pocket to the arrival of the iPhone in 2007. Yet that simple idea has done more than any other recent technological innovation to transform the way the world computes. Tracing the roots of the smartphone captures the era when computing went from being personal to being intimate.

General Magic itself would become one of the Valley's more notable failures, but Fadell and Rubin would go on separately to lead the teams that built the first iPhone and first Android smartphones. Today the vast majority of the world's smartphones have evolved from their original hardware designs.

Now that there are more than two billion smartphones in the world, it is difficult to grasp how extraordinary it is that it can all be traced to a single office cubicle in Mountain View, California.

Fadell and Rubin were part of a small "Band of Brothers" in Silicon Valley—they were almost all male—who, beginning in the mid-1980s, would form the nucleus of a generation of engineers that reshaped both the modern computing world and Silicon Valley's culture.

They were friends, enemies, competitors, and co-conspirators, and they shared a passion for a Silicon Valley ideal that went beyond either computer hacking or venture capital greed. They came of age in the wake of Apple's Macintosh project, a romantic crusade by a "pirate" team of engineers led by Steve Jobs.

The Macintosh had exploded on the world in 1984. Yet for all its impact on popular culture it made an even deeper impression on the young group of engineers who came to believe they could build computers that would change the world.

Together they would come to personify a new culture that took hold in the Valley based not on starting companies, or going public, but rather upon the ideal of "shipping" computers that would reach hundreds of millions or even billions of people.

It was something that Steve Jobs had drilled in to them: "Real artists ship," he intoned at an early Macintosh team off-site.

They had been seduced by the allure of the Macintosh experience that led them to believe that all they needed was one good idea, and they in turn could design the Next Big Thing.

Yet the Macintosh was not an immediate commercial success, and in 1987, Steve Jobs was forced out of a company he had founded a decade earlier with his high school friend Steven Wozniak. While what was arguably the first computing appliance had not succeeded financially, it captured the romantic ideal of a small team of engineers acting as a rebel alliance struggling against the empire—at the time personified by IBM.

In 1985 the Macintosh appeared to have failed, and over the next half decade, in groups of twos and threes, the young engineers set out on their own.

The first era of handheld computing would be defined by four efforts—Apple's Newton, the General Magic Communicator, Go. Corp, and Palm Computing. All would eventually fail in one fashion or another, but their collective failure would become an essential bridge to our modern computing world.

Today smartphones—internet-connected, pocket-size supercomputers and tablets—are now so ubiquitous that they are taken for granted. In the almost decade since the iPhone was introduced in 2007, smartphones have fulfilled Arthur C. Clarke's dictum that "any sufficiently advanced technology is indistinguishable from magic."

However, until the mid-1980s, Silicon Valley had been principally driven by the idea of desktop personal computing. It was an idea that emerged from the three computer science research laboratories that had been established around Stanford University in the 1960s and 1970s.

There had been early outliers. Computer scientist Alan Kay, who began demonstrating a mockup of a tablet computer he described as a "Dynabook" beginning in the late 1960s was first. His insight broke from the original concept that Doug Engelbart and J. C. R. Licklider had shared in the early 1960s. They had conceived of a computer that would be something that you would use to "drive" through the network world, which had then not yet been named cyberspace by science fiction author William Gibson. In contrast, Kay was the first to grasp the concept that computing was instead a universal "media" in its own right and that it in turn would transform all other media—the printed word, sound, and video.

Yet Kay envisioned a slate computer that would be mocked up in Apple's famous Knowledge Navigator video in 1987. It would take one more step to move computing from the lap to the palm of your hand. That shift emerged steadily during the late 1980s. One of the people who drove it was a young former Palo Alto political activist, Marc Porat, who stumbled upon Daniel Bell's *The Coming of Post-Industrial Society* in the Stanford University library. He decided he could put Bell's rambling ideas into practice. His doctoral dissertation coined the phrase "information economy."

Then he took his ideas a step further. Not a technologist in any sense of the word, in 1988 he brought the notion of a "Pocket Crystal" to Apple and became a crusader for the idea inside the company. He had been thinking deeply about the idea of an information economy for more than a decade, and before arriving at Apple, he sat one day in Café Un Deux Trois on 44th St. near Times Square and drew three overlapping circles on a sheet of paper. One was labeled content, another was communications, and a third was computing. It was an epiphany that computing would provide an information utility you would hold in your hand. It would be a "Pocket Crystal." Soon thereafter he would take the idea to Larry Tesler who was running Apple's Advanced Technology Group.

Similar ideas were bubbling up all over Silicon Valley. The idea of handheld computing took hold among the young generation engineers who had grown up in the wake of the introduction of the Macintosh, and simultaneously elsewhere in the Valley.

A similar thought hit Jerry Kaplan, an artificial intelligence researcher who was then the chief technology officer of Lotus Development Corp., on a flight aboard Lotus founder Mitch Kapor's corporate jet. Kapor had an unwieldy "luggable" Compaq Computer, and he was entering information from an array of yellow sticky notes that were plastered everywhere. The idea of "pen computing" was an obvious one. Soon thereafter Kaplan founded Go Corp. and eventually ran the company into an epic clash with Microsoft—which he lost.

But the idea of a handheld device with the power of a personal computer was taking deep root all over the Valley beginning in the late 1980s. At Apple it led to political intrigue as chief executive officer John Sculley attempted to sort out all of the competing ideas. The Pocket Crystal group, including Porat, talented engineers like Rubin and Steve Perlman, and Mac software veterans Bill Atkinson and Andy Hertzfeld, were ushered out the door to form General Magic. The company set out to build Porat's handheld communicator but never succeeded.

Inside Apple another young engineer, Paul Mercer, had begun building his own prototypes of handheld devices merged with Macintosh software. He gave them code names like "Swatch" and "Rolex." Separately, Steve Sakoman brought his experience inside Hewlett Packard's calculator division and came to Apple with the idea of the Newton after a brief flirtation with Kapor and Go. Mercer's efforts were shelved and he joined the Newton project. Later he would leave Apple and start Pixo, a small software development effort. Tony Fadell would use the Pixo software to help develop the original iPod.

It soon became a deluge.

Although women were largely absent, there were notable exceptions. Donna Dubinsky left Apple's Claris subsidiary in 1991 and the following year co-founded Palm Computing with Jeff Hawkins. And in the Newton Project, Donna Auguste, a UC Berkeley–educated engineer became a key member of the team.

They were part of what would become Silicon Valley's most important generation. Collectively they sensed that computing was something that would literally disappear. A decade later the iPod and the iPhone would be the first two consumer devices to successfully embody the ideal. Silicon Valley was on its way to what Xerox PARC computer scientist Marc Weiser had identified as "ubiquitous computing"—a world in which computing literally disappeared into everyday objects—and they would become magical. ○

THE NET IS EATING SOFTWARE

BY MARC WEBER
CURATORIAL DIRECTOR,
INTERNET HISTORY PROGRAM

When you put something online, will it be:

a) Saved forever

b) Erased faster than you can say "merger and acquisition"

c) Saved forever if an embarrassing photo, deleted if it really matters

d) All of the above

Many people assume A), that anything they put online will be "automagically" saved for all time, from a school paper to Instagram photos. Others, often those with professional experience in digital preservation, cynically assume B), that almost nothing will survive, especially for commercial sites that could be bought out anytime. C) is just my personal conviction.

The correct answer is D), all of the above, since some bits of information out of the gazillions we generate each day will follow each of the three scenarios. The only certainty is that what gets preserved will be less than most people think. The results will also be more uneven than preservation has been in the age of paper. That's because the units that people routinely decide to keep or toss are no longer a book or even a filing cabinet. Today, information is lost or (occasionally) saved in great gulps, like the hundreds of millions of virtual pages that make up an interconnected website or cloud-based service.

When I started the Internet History Program at CHM eight years ago, the issues described above were mostly confined to the online world—the web and the internet. Much software was still sold in standalone packages, like the CDs you would take home and install on your computer. Commercial software was often a scaled-up version of the same idea. IT departments would install a particular software package on the firm's computers and then back up the resulting data on tape.

But today, once-standalone software, from word processing to payroll systems, is melting in a cloud of "software as a service" and other highly networked applications. This means the kinds of problems once confined to studying and preserving the online world are expanding to envelop nearly everything we do on computers. No longer do software packages come out at intervals stamped with meaningful version numbers and documented with a set of easily collectible manuals. For newer software, the "system requirements" to run are no longer a single machine or even a single company's network but an entire warehouse-size data center with its hundreds of racks of interconnected servers, all in various changing states of upgrades and relationships with each other and with services from yet other data centers. Social sites and services add another level of complexity. Even when preserved they are nearly meaningless without interaction from live users.

A small but telling sign of this cloudward migration is within the Museum's major new exhibition on the social role of software: *Make Software: Change the World!* When colleagues and I began curating it five years ago, four of the seven galleries were about networked software: MP3, Wikipedia, Texting, and *World of Warcraft*. Today it's five out of seven. Photoshop—which had been a standalone package since its start in the 1980s—can now only be bought with a yearly license, renewed and downloaded from the cloud. Beyond the exhibition, venerable packages like Microsoft Word are moving toward the same model. And newer software, like the cloud-based CRM software pioneered by Salesforce, often starts online.

The new exhibition is part of a major new three-part emphasis on software at CHM. For exhibits, there is *Make Software,* plus temporary exhibits like the one we hosted last summer around GeoCities. All 38 million user pages on this leading social site of the 1990s were scheduled for deletion, until hacker archivists and the Internet Archive managed to save a substantial portion at the 11th hour.

Curatorially, we're building on over a decade of work around both standalone and networked software with a new Center for Software History. But most important of all, we are massively expanding our digital repository to preserve even more software and data of all kinds. To really understand the issues at stake, it helps to step back a few thousand years.

The Ourobouros Effect

Transitions to new society-wide media make for interesting times. Homer is a kind of last gasp preserved in amber of the oral tradition in ancient Greece; ditto with Gilgamesh for Sumeria. As ancient bards died out without successors, written records became the only form in which some of the old tales lived on. But those eras had the advantage of moving from a volatile medium to a more durable one—in the case of clay tablets, to one that can get even more permanent when baked by fires! Much of what we know of the ancient Near East comes from the contents of libraries and archives razed in war—tens of thousands of tablets to date.

We are now moving the other way, from the permanent to the ephemeral. In fact, we might compare digital media to an oral tradition. Paper can last for centuries. It needs to be actively destroyed. As a result it often gets saved by accident, in attics and basement file cabinets. It also sticks around long enough for traditional archiving procedures, the ones we've developed over the five millennia of writing.

By contrast, digital files and oral traditions alike need to be actively preserved. Unless they get regularly re-copied to new media, whether hard disks or the minds of young apprentices, they simply disappear.

As more and more information goes digital—first software, now email, and journalism, and books, with more to come—what will happen? There's a possible precedent. Our records of the transition from writing back to an oral tradition after the fall of the Roman Empire are very poor. That's why we call that period the Dark Ages. It doesn't mean they felt dark at the time. In 700s France you probably had a keen sense of current events and their ties to the past, all via word of mouth, as we do from Twitter feeds, blogs, and Facebook today. But that unwritten record is gone.

There's little reason to hope the early years of our new online world will fare much better.

Of course, society will eventually figure out how to preserve the digital bits it really wants. For many fields, whether insurance or art history, the awkward transition period we're living through will just be some spotty gaps in a larger arc. But for the study and the history of online systems and connected software, these early events are as important, and singular, as the Crucifixion is for Catholics, or the Revolution for American history. To lose them is to orphan the field.

The Ouroboros is the name for the ancient symbol of a snake with its own tail in its mouth. While usually seen as a symbol of renewal or cyclical replenishment, the snake is shown actually eating itself.

//////

Today's online world may be the first technological revolution that, if it fully succeeds, can erase much of its own history by transferring it to a perishable medium.

Modern correspondence has already gone missing from an archival point of view, yesterday's durable letters transmuted into a vaporous cloud of rarely preserved emails, texts, and chat. Routine documents, from meeting reports to proposals to résumés and presentations, have also gone digital. Magazines are well on their way. Books are next.

We aren't just losing information shared between people. Many of the great machines that have powered the information revolution of the past 50 years are fading like snow in spring rain. We call those machines software.

Older machines either survived or didn't. The London Science Museum's vaults are filled with fantastic gizmos from the Crystal Palace exhibition of 1851. The physical husks of today's digital machines often get preserved too—the hardware. But functionally that's like a watch museum full of empty watch cases. Computers are, by definition, "universal machines," so named because their hardware is just a general player for the real machinery—the code that they execute! And that has rarely been saved.

A modest silver lining is that with digital preservation, small efforts have an outsized impact. Because digital media is so efficient in terms of both cost and storage capacity, some can be nearly as easy to preserve as they are to destroy. While there are a few technical issues around incompatible preservation formats, and re-copying data to new media every decade or so, institutions like the Internet Archive worked out practical solutions back in the 1990s. One person taking home the right box of tapes or disks can easily save a city library's worth of material, or software equivalent to a warehouse full of machinery. But it will take time to integrate digital preservation into routine procedures, a luxury many digital artifacts can't afford.

It will also take will. The problems with preserving cloud-based material are mostly not technical, but about who has control. With standalone software, customers physically possessed both the program they had bought and the data generated with it. With software as a service, they often have neither. A download of a customer's own data can be meaningless without

Hierarchy of Digital "Preservability" for Software

1. SOURCE CODE PRINTED ON PAPER
2. SHRINK-WRAPPED CONSUMER SOFTWARE, MULTIMEDIA CD-ROMs
3. SHRINK-WRAPPED PROFESSIONAL SOFTWARE AND SYSTEM SOFTWARE
4. PUNCHED CARDS
5. STANDALONE ENTERPRISE SOFTWARE
6. SIMPLE WEBSITES
7. LOCALLY NETWORKED SOFTWARE
8. COMPLEX AND SOCIAL WEBSITES
9. CLOUD SOFTWARE AND DATA

the exact version of cloud-based software it needs to run. Even the apps "on" our phones are merely a cute interface to the main software on a server somewhere.

The result? If tomorrow's software is to be meaningfully preserved, the institutions that make and host it need to be a big part of the process. That will require a tectonic shift in the way the industry has evolved so far. Otherwise, future researchers will be mostly left with some screen-shots, descriptions, and video of the software in action. That last resort has already been reached by scholars of virtual worlds.

It's ironic that just as scholars and others are waking up to the importance of software and starting to get their minds around what it is, how to study it, how it relates to society and to technology, the thing itself is morphing and slipping from our grasp.

Arthur C. Clarke's story "History Lesson" tells of a distant future where aliens find the only remaining relic of human art or literature—Mickey Mouse movies. Their archeologists take the animated movies as fact and spend centuries painstakingly extrapolating an entire way of life based on a race of cute rodents with a propensity for madcap escapades and violence.

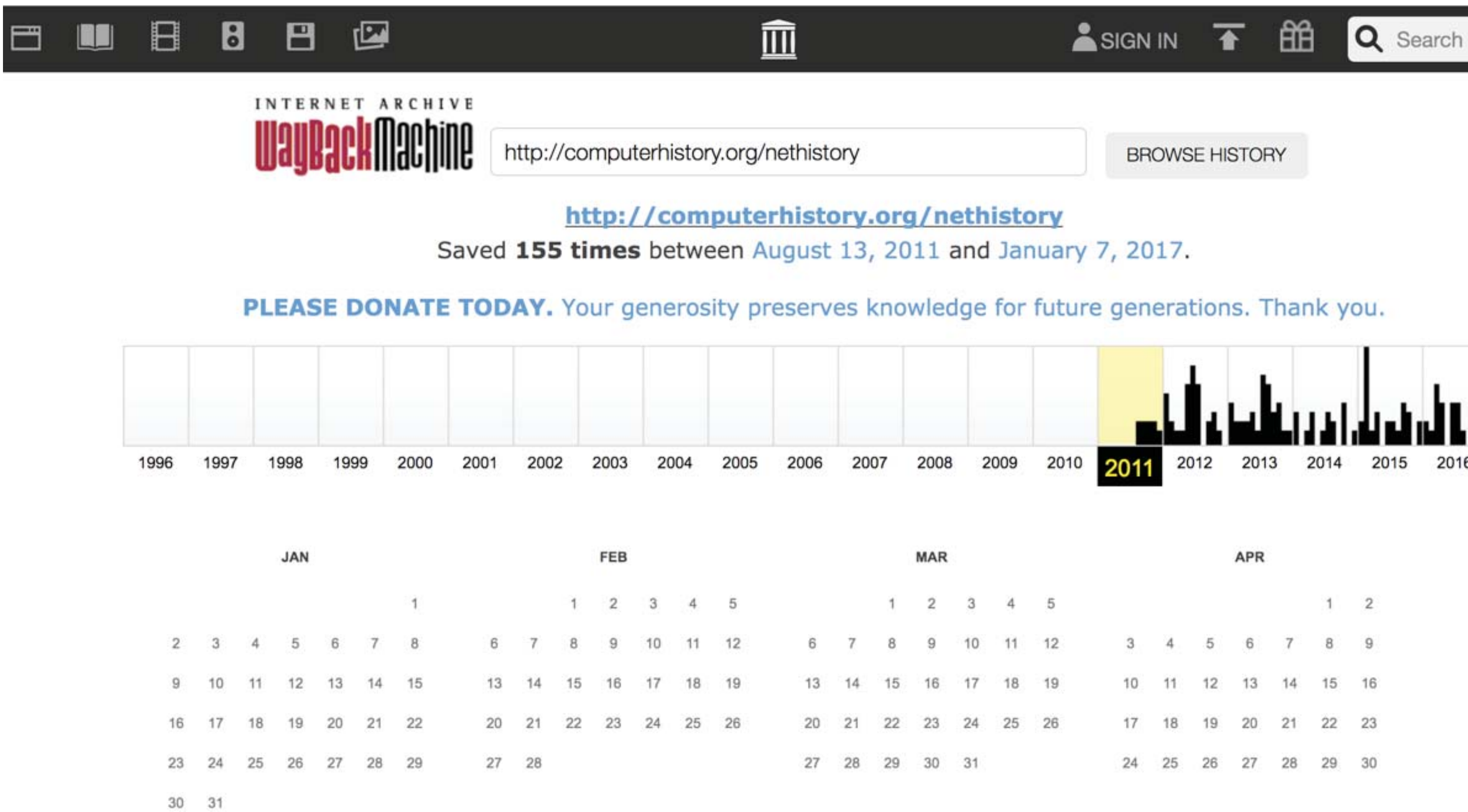
Today, standalone computer games are the only class of software that is routinely well preserved. Life may yet imitate art. ○

Portions of this article were previously published in a slightly different form in *Information and Culture*, and shall be published in *Webs*, a forthcoming book by the author from Thomas Dunne Books/St. Martin's Press.

About the Internet History Program: The Internet History Program at the Computer History Museum (CHM) records the history of the online world, including the web, the internet, and mobile data. Launched in 2009, it is one of the first general programs in this area by a major historical institution. The program addresses networking as both a technical invention and a new mass medium with a growing role in society. Its main work includes growing CHM's world-class collection of networking history materials, scholarly activities, developing public events, and curating both permanent and temporary exhibits related to the online world.

Curatorial Director Marc Weber has researched the history of the web since 1995 and co-founded two of the first organizations in the field. The program works with CHM staff, trustees, and outside advisors with special expertise in networking, including many pioneers. It collaborates with peer institutions worldwide.

While the Internet Archive has preserved basic web pages since 1996, it often can't save the proprietary data and software behind those pages.



This cheerful welcome page greeted visitors to GeoCities in its 1990s heyday. It would reach 38 million pages, tens of millions of which are preserved by the Internet Archive.

Salesforce.com helped suck traditional corporate software up into "the cloud."

BY HANSEN HSU
CURATOR, CENTER FOR
SOFTWARE HISTORY

A SHORT HISTORY OF OBJECTIVE-C

To date, users have downloaded over 140 billion apps to their iPhones.[1] The iPhone's success is tied to its ecosystem of third-party apps. When the App Store debuted in 2008, all apps were written in a programming language that few outside the Apple community had ever used: Objective-C. Since then, Objective-C's usage has exploded in a gold rush of developers making apps. Although Apple introduced its new Swift language in 2014, most of Apple's iOS operating system is still written in Objective-C, so it will be on Apple devices for years to come.

While most programmers discovered Objective-C only during the iPhone app revolution, Objective-C has been around for over 30 years. Objective-C has been the foundation of Apple's desktop operating system, Mac OS X, since its debut in 2001, and was also the basis for NEXTSTEP—OS X's immediate ancestor—created by Steve Jobs' NeXT Computer Inc. However, Objective-C was created neither by Apple nor NeXT. Its origin was a small Connecticut startup in the early 1980s called Stepstone.

Objective-C's early history and later evolution at NeXT are not well known, and there are very few available sources. At CHM, we recently acquired an essay on the "History of Objective-C," co-written by Brad Cox and Steve Naroff, submitted to the third History of Programming Languages Conference in 2007, but never published. I have also conducted an oral history with Cox, the language's initial creator, and with Blaine Garst, a NeXT engineer who later contributed to Objective-C. These sources, in addition to an earlier interview I conducted with Naroff, are the basis for the following history.

The ideas that led to Objective-C originated in a division of International Telephone and Telegraph (ITT), where Tom Love and Brad Cox were looking for ways to improve the productivity of programmers. In 1981 a special issue of *Byte* magazine described a revolutionary new programming language, Smalltalk, that had been developed by Alan Kay's team at Xerox PARC. Smalltalk represented a radically new way to think about creating programs, which Kay called "object-oriented." Rather than write a program as a series of actions ("procedures"), which take data as inputs, a program would be re-oriented around the data itself, grouped together inside "objects." Smalltalk envisioned programs as collections of objects, which would send messages to each other, causing them to invoke "methods" (perform actions). The methods invoked were selected "dynamically," that is, while the program was running. Thus, a Smalltalk program can modify itself in real-time, in response to user input.

Cox saw enormous productivity advantages in a language like Smalltalk. He imagined that it would allow him and Love to create libraries of objects that could be mixed and matched like Legos. Rather than having to write everything from scratch, a programmer could use existing, or "prefabricated," objects to rapidly create a new program. Cox envisioned a future in which object libraries would be bought and sold, ushering in a software industrial revolution with these "interchangeable" parts.

Smalltalk, however, had several drawbacks. It was slow, it was Xerox's technology, and it required all programs written in it to run in a special environment. Cox and Love were committed to using Bell Labs' UNIX, a relatively open system, with a large existing base of programs written in C. C was a language that made for fast, efficient programs. Cox came up with the idea to marry Smalltalk's object-oriented ideas with C and published this work in a 1983 paper, calling it the Object-Oriented Precompiler (OOPC). Cox intentionally made it as simple as possible, thinking of it as a "soldering gun" that would weld object-oriented programming onto C. Cox contrasted this with Bell Labs' new language C++, which also combined C and object-oriented programming, but in a much more complex way, which Cox compared to a fabrication plant.

After encountering resistance at ITT, and a brief period at Schlumberger, Love and Cox started their own company to bring these ideas to market, originally called Productivity Products International, and later Stepstone. Cox rewrote the OOPC with a new compiler and renamed the language Objective-C. Nevertheless, it still involved a translation of Objective-C code into regular C code. Love specified some aspects of its design, including the decision to make it a hybrid language with two conceptual levels, with higher-level object-oriented code literally bracketed off from procedural C code by square bracket characters.

With the company's focus on selling object libraries written using Objective-C, Cox shifted his focus to these libraries. Stepstone also licensed the Objective-C language to customers, many of whom asked for changes or new features. Cox hired a group to handle the development of the language, and it began to add

First licensed by Stepstone to NeXT for the company's NEXTSTEP operating system, Objective-C would later power Apple's OS X and iOS operating systems.

features like garbage collection and an interpreter. These were underway when Stepstone's object libraries business dried up and the company folded.

One of Stepstone's Objective-C customers, however, radically changed the direction and prospects of Objective-C. In 1988 Steve Jobs' NeXT Computer licensed Objective-C from Stepstone as the language for its NEXTSTEP development environment. Steve Naroff had been hired into Stepstone's language team in 1986 for his experience with MAINSAIL, a language developed at the Stanford Artificial Intelligence Laboratory. Naroff became NeXT's biggest advocate within Stepstone and the primary engineer responsible for addressing NeXT's needs within Objective-C. Ultimately, Naroff left Stepstone to become a NeXT employee, where he was responsible for the Objective-C compiler. In 1995 a failing Stepstone sold the total rights for Objective-C to NeXT, which then went to Apple when it acquired NeXT in late 1996.

Naroff made significant changes to the language, and as a result, the form Objective-C took under NeXT and later Apple is significantly different than the version originally developed by Cox. Two new signature features would be indelibly associated with Objective-C in later years. The first was called "categories" (today known as "extensions"). Categories allowed programmers to add their own functions to library objects flexibly and globally. Categories were added to Objective-C by Naroff in 1988 to facilitate Interface Builder, a visual programming tool that helped developers create graphical user interface applications more quickly on NEXTSTEP than on other platforms. A second key feature was added by NeXT engineers Blaine Garst and Bertrand Serlet in 1990, called "protocols," based in part on Garst's earlier work on modular programming and fast inter-process communication. Garst immediately used this new feature to allow objects to message each other even while distributed over a network. Protocols were later incorporated into Java, which calls the feature "interfaces."

These two features built upon a key advantage Objective-C had over C++: a "dynamic runtime." Inspired by Smalltalk, this system let programmers modify the behavior of objects "dynamically" (meaning while the program was running), enabling them to alter portions of NeXT's object libraries piecemeal, without breaking them for other programmers. This gave programmers both the flexibility to adapt to the future and compatibility with the past. In addition, NeXT's Objective-C runtime was more efficient than Smalltalk's, allowing it to be used across NeXT's operating system, even where high performance was required.

This combination of features—categories, protocols, and the dynamic runtime—allowed NeXT to create the AppKit, an object-oriented library for developing graphical applications that is still used by Apple today. Despite NeXT's low market share, developers who cut their teeth on NeXT machines loved it. NeXT never became the giant success Jobs had envisioned until 1996, when Apple bought NeXT. Since then, software written in Objective-C has powered almost all of its major new products: Mac OS X, the iPhone, iPad, AppleTV, and Apple Watch.

The story of Objective-C and NeXT shows how much influence users can have on the development of a technology. Until 1995, Objective-C was owned and produced by Stepstone, and NeXT was its user. Nevertheless, NeXT was able to have Objective-C modified to suit its needs, eventually taking over as its developer. Brad Cox and Tom Love were Objective-C's inventors, but it was Steve Naroff, Blaine Garst, Bertrand Serlet, and others at NeXT who transformed it into the language behind the iPhone today.

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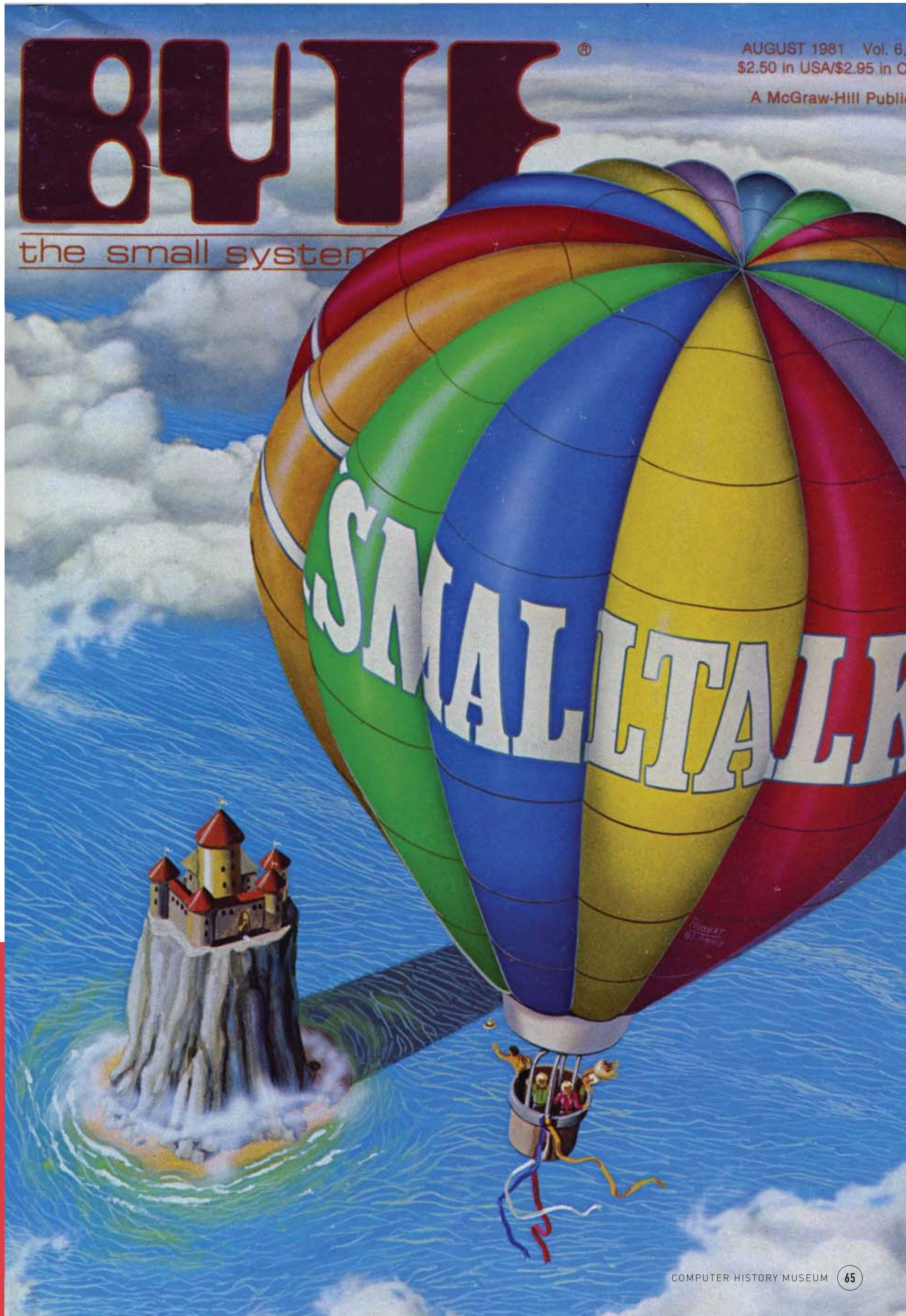
[1] According to Tim Cook in his iPhone launch event on September 7, 2016.



The 1981 issue of *Byte* magazine featured Xerox's Smalltalk, a groundbreaking graphical environment and programming language that introduced object-oriented programming to a large audience.

BY DAG SPICER
SENIOR CURATOR

BY DAVID C. BROCK
DIRECTOR, CENTER FOR SOFTWARE HISTORY

RECENT ARTIFACT DONATIONS

COLLECTION

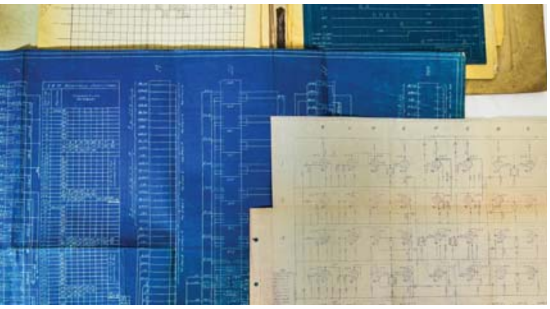
ILLIAC IV MODEL, BURROUGHS CORPORATION, US

CHM #: X7957.2017
Date: ca. 1971
Donor: Gift of Catherine Schulbach

The ILLIAC IV supercomputer project, begun in 1965 and finally resulting in a functioning supercomputer in 1972, was based on an innovative "massively parallel" design. This meant making a "computer of computers" in which many computer processors would work on pieces of a large problem together. ILLIAC IV was installed at the NASA Ames Research Center in Mountain View, California.

To boost speed, ILLIAC IV used 64 different processors. On certain scientific and engineering problems, it showed impressive performance and its design was perfectly adapted to the computational fluid dynamics problems NASA solves on a daily basis. Nonetheless, the project itself was overly complex, took much longer than expected to complete, and resulted in a system only one quarter of the intended size (it was to have 256 processors).

This wood and paper model was used to secure government funding for the project and help with the design of the building in which it would be housed.

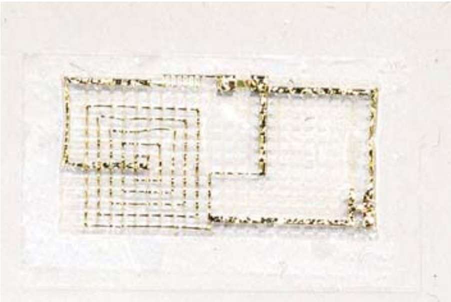


ENIAC DRAWING SET, US

CHM #: X7776.2016
Date: 1948
Donor: Gift of Joseph F. Cherney

The ENIAC, completed in 1946, was the world's earliest large-scale programmable computer system. Engineer Joe Cherney worked on ENIAC from 1950 to 1953, during which time he led the maintenance team that kept the machine's 18,000 vacuum tubes operating reliably. In 2016, 70 years after ENIAC's birth, Cherney donated an extensive drawing set of ENIAC to the Museum, documents of extreme rarity. Besides showing the circuitry of ENIAC via schematic diagrams, it includes tabular listings of how problems were "set up" on ENIAC and a drawing set of the magnetic core memory upgrade to ENIAC (1952), an improvement that transformed ENIAC into a truly stored-program machine—the hallmark of computers today.

Remarkably, Cherney came to the attention of the Museum when CHM docent Jeff Katz overheard visitors in *Revolution: The First 2000 Years of Computin*g describing how a man in a period ENIAC photo was their relative, Joe Cherney. The Museum invited Cherney to participate in a series of oral history interviews about his career and the history of ENIAC, which eventually led to this remarkable donation.



PROTOTYPE "TRANSIENT ELECTRONICS" DEVICE, UNIVERSITY OF ILLINOIS, US

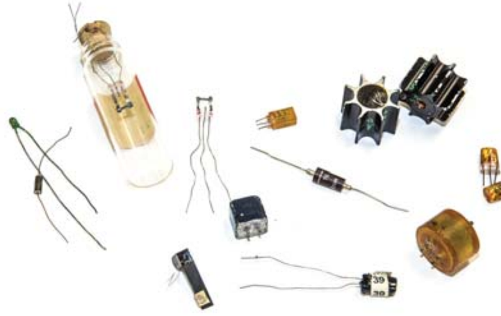
CHM #: X7870.2017
Date: 2016
Donor: Gift of Professor John A. Rogers

Since the early 1960s, one of the hallmarks of integrated circuits has been their stability and reliability. Indeed, this stability was one of their great attractions for aerospace applications during the Cold War. This prototype integrated circuit—fabricated in 2016 for the Museum by Dr. Seung-Kyun Kang at the request of Professor John A. Rogers—is an example of a deliberately *unstable* device: a biodegradable integrated circuit, an example of what Rogers calls "physically transient electronics."

Transient electronic devices, like this prototype, have several imagined uses that center on their deliberate instability: implanted medical devices that harmlessly dissolve into the body, environmental sensors of various kinds that fully decompose into the landscape, and consumer electronics that minimize waste and the need for recycling.

This prototype is a demonstration platform for the idea of transient electronic devices, with a set of different components fabricated on a biodegradable, thin silk substrate. The components include a magnesium-based inductor, capacitor, resistor, and interconnect as well as a silicon diode and a silicon-magnesium-magnesium oxide transistor.

The Museum's prototype may last one to two years, and staff is documenting its disintegration with periodic photographs.



PAUL SULLIVAN SEMICONDUCTOR COLLECTION, US

CHM #: X7957.2017
Date: ca. 1948–1955
Donor: Gift of Pat Belotti

The history of the transistor, from which today's integrated circuits are made, begins in earnest in the 1950s. It is a story of many failed experiments, struggles to grasp the fundamental physics of these new devices, and of trying to make working transistors in large quantities. Transistors from this era are extremely rare, having been long ago consigned to the landfill or recycle bin.

It was a big surprise, then, when the Museum received a unique collection of such transistors from former Raytheon engineer Paul Sullivan, via his family. Sullivan's collection is what transistor historian Jack Ward has called "an instant world-class collection of early and important semiconductor devices." The collection includes laboratory prototypes from the dawn of the transistor age to early commercial devices from Raytheon, Sylvania, RCA, Philco, and others.

DONOR PROFILE

RAY AND MEREDITH ROTHROCK INVEST IN THE MUSEUM'S NEW EXPONENTIAL CENTER

BY PAMELA GESME MILLER
ASSOCIATE VICE PRESIDENT OF DEVELOPMENT

When venture capitalist Ray Rothrock, chairman and CEO of RedSeal Inc., was approached in 2014 by a fellow CHM donor about initial support for the Museum's new Center for Entrepreneurial Company Building (now officially the Exponential Center), "he was convinced within two minutes to support this new center because he loves technology and history." Therefore, the Museum, being the intersection of those two areas of interest, was the perfect vehicle for his and wife Meredith's philanthropy.

The Rothrocks support education on every level and at its core, the Museum's Exponential Center exists to "preserve and educate." The Rothrocks are one of the "lead founding investors" of the Exponential Center through their significant support, and Ray knows about investing. Prior to RedSeal, he was at Venrock Associates for 25 years, retiring as managing general partner in 2013. As a result of his excellent track record, Ray was on *Forbes*' "The Midas List" in both 2012 and 2013, ranking #49 and #63, respectively. As a venture capitalist, Ray assisted entrepreneurs in achieving their dreams, while also producing outstanding financial returns for his partners. He enjoyed the process of personally discovering, creating, and guiding more than 50 companies through their early stages of formation and emerging growth. Additionally, a vast knowledge of technology has helped Ray to identify trends and one of the keys to being a successful venture capitalist is "pattern recognition."

A 1988 graduate of Harvard Business School (HBS), Ray was attending an HBS reunion when he first visited The Computer Museum (TCM) in downtown Boston. He was fascinated with the artifacts on display! In 1996, TCM moved its historical collection west to Moffett Field in Mountain View, California, and The Computer Museum History Center was established (later renamed the Computer History Museum). In 1999, the Boston computer museum closed and many of its world-class artifacts were transferred to Mountain View—and the rest, as they say, is history! Rothrock watched with interest this progression from Boston to the Museum's eventual home in Silicon Valley.

In addition to an MBA (with Distinction) from HBS, Ray earned his bachelor's degree in nuclear engineering from Texas A&M University (Summa Cum Laude) and his master's degree in nuclear engineering from the Massachusetts Institute of Technology (MIT).

As a young man, Ray enjoyed working with electricity, amateur radio, and electronics, and his technology expertise evolved from those early learning experiences. Rothrock's father attended biennial WWII veteran reunions in Philadelphia, where Ray would visit the Benjamin Franklin Museum to learn about inventions such as the steam engine. He also looked forward to each edition of American Heritage, a quarterly magazine dedicated to the history of technology.

Suffice it to say, that Ray has spent a lifetime loving and learning about technology of all kinds and so CHM and, specifically, its new Exponential Center, is a natural place for their support. The Rothrocks are helping to make it possible for the Exponential Center to capture the legacy—and advance the future—of entrepreneurship and innovation in Silicon Valley and around the world.

Meredith and Ray reside in Portola Valley, California, and when entertaining out-of-town visitors, Ray insists they see the Hoover Tower on Stanford University's campus and the Computer History Museum (not necessarily in that order). ○

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The Computer History Museum (CHM) is the world's leading institution exploring the history of computing and its ongoing impact on society. CHM is dedicated to the preservation and celebration of computer history and is home to the largest international collection of computing artifacts in the world, encompassing computer hardware, software, documentation, ephemera, photographs, oral histories, and moving images.

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Wed, Thurs, Sat & Sun
10 a.m. to 5 p.m.

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