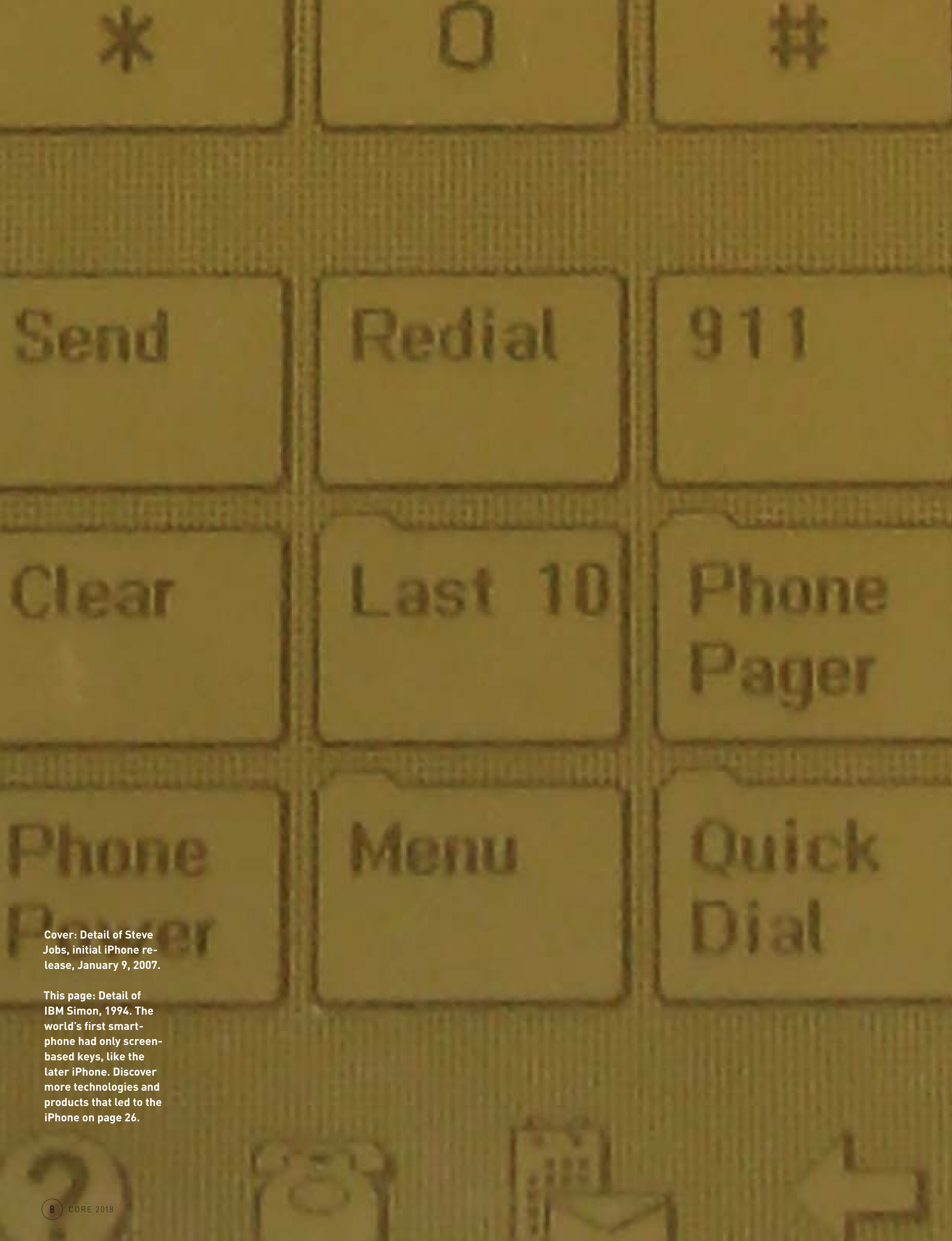
2018

CORE

A Publication of
the Computer
History Museum

iPhone 360 Feature
Reimagining Live Programming
Creating a Culture of Learning



Cover: Detail of Steve Jobs, initial iPhone release, January 9, 2007.

This page: Detail of IBM Simon, 1994. The world's first smartphone had only screen-based keys, like the later iPhone. Discover more technologies and products that led to the iPhone on page 26.

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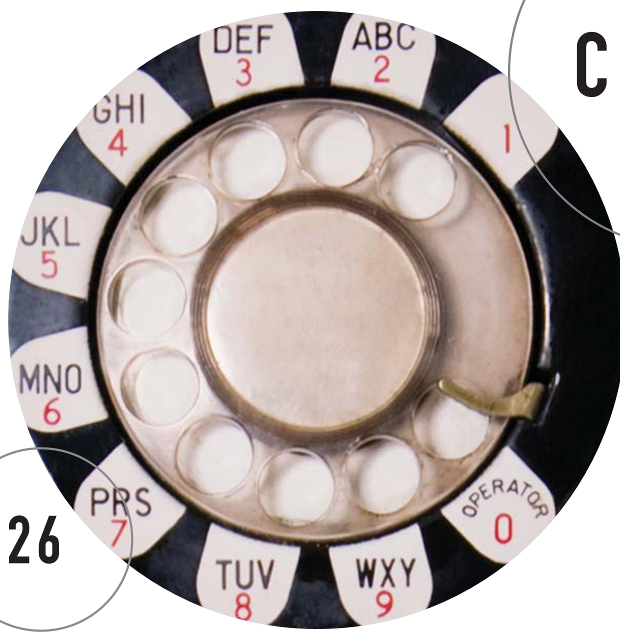

COVER: COURTESY OF PHOTOGRAPHER PETER BELANGER

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Marguerite Gong Hancock is the founding executive director of the Exponential Center at the Computer History Museum. She is an expert on innovation and entrepreneurship in high-tech regions around the world, with two decades of experience at Stanford University leading international and interdisciplinary research and education programs on entrepreneurship and innovation.

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Hansen Hsu is curator of the Center for Software History at the Computer History Museum. Hsu worked at Apple from 1999–2005 on Mac OS X as a QA engineer. He received a PhD in science and technology studies from Cornell in 2015, studying the culture and values of the Mac and iPhone developer community.

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AUTHOR & HISTORIAN

Pulitzer Prize–winning journalist John Markoff joined the Computer History Museum as a historian in 2017, after nearly three decades as a technology writer for the *New York Times*. His books include *What the Dormouse Said: How the Sixties Counterculture Shaped the Personal Computer Industry* (2005) and *Machines of Loving Grace: The Quest for Common Ground between Humans and Robots* (2015).

MARC WEBER

CURATORIAL DIRECTOR, INTERNET HISTORY PROGRAM

Marc Weber is founder and curatorial director of the Computer History Museum's Internet History Program. He launched web history as a topic starting in 1995 with crucial help from Tim Berners-Lee and other pioneers and cofounded two of the first organizations in the field. Weber writes, speaks, and consults widely on the history of the online world.

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CHAIRMAN'S LETTER

THE 360° VIEW

In an early promotional video for the Computer History Museum (CHM), our founding father Gordon Bell—never one to avoid a provocative superlative—looks directly at the camera and says, "I happen to believe that the computer is the greatest invention …" He pauses, looking for an inspired way to the end the sentence. "Ever."

It's hard to disagree. The computer is changing everything about our world in a way no other invention ever has. That has propelled us to change too—to "reimagine" the Museum, to address new topics and reach new audiences—so that we understand and celebrate the full impact of computing in addition to its remarkable history. We take in a 360-degree view that includes makers, users, consequences, opportunities, and risks.

This issue of *Core* reflects how we are increasing diversity of our activities in the following ways:

- **Expanding** our live public programs to include timely stories of people and computing today
- **Increasing** the use of our collection and interpretation at institutions around the world
- **Integrating** education more fully into all our activities and exploring innovative uses of our new dedicated education space
- **Using** the iPhone as the subject of a prototype project that takes a 360-degree view of companies and products, covering their many aspects: engineering, social, business, political, manufacturing, environmental, and government policy
- **Studying** hidden design assumptions that might unintentionally introduce prejudice
- **Continuing** our aggressive acquisition of oral histories and materials from our CHM Fellows and others so that we can paint a complete picture of these technological heroes

A museum is the perfect institution for this broad array of activities. Most progressive museums have moved, as we have, far beyond the traditional definition as "a place where objects of historical, artistic, or scientific interest are exhibited, preserved, or studied." As Kirsten Tashev, our amazing vice president of Collections and Exhibitions says, "Museums have so many awesome tools to reach their audience and achieve their mission: events, exhibits, programs, collections, media, films, blogs, websites, etc. Society needs museums, which are simultaneously a constant in a changing world and a mirror of our ever-changing interests."

The Museum is undergoing exciting growth, and we are delighted to have Dan'l Lewin as our new president and chief executive officer to lead the expansion. Dan'l is a well-connected industry veteran who understands how computing is changing and impacting our world.

The change to come will dwarf the change that has been, both for computing and for the Museum. Stay with us as we ride the wave!

Len Shustek

LEN SHUSTEK
CHAIRMAN OF THE BOARD OF TRUSTEES

MUSEUM UPDATES

PROGRAMS

FROM BIG NAMES TO BIG IDEAS: REIMAGINING LIVE PROGRAMMING

BY LAUREN MIYAMOTO
MANAGING PRODUCER, CHM LIVE

Technological change is born through extraordinary ideas, flashes of creativity, and thinking differently. What is it that inspires computing's greatest entrepreneurs, engineers, and leaders? Often, it is as simple as a quote, a question, an anecdote, a statistic—a singular instance in time.

For Bob Noyce, an introduction to the first transistor in a Grinnell College physics class launched a lifelong obsession with the device's capabilities. For Steve Jobs, a visit to an Oregon Apple farm inspired him to name one of the world's most iconic technology companies. For Jack Dorsey, a childhood interest in emergency dispatching helped him see technology as a tool to understand what was happening in his city in real time.

Through our CHM Live programming series, we aim to provide similar mind-opening moments to encourage audiences to think about technology in new ways. To see their curiosity and creativity reflected in the stories of our speakers. To envision their own role in the revolutionary story of computing.

The innovations produced by Noyce, Jobs, Dorsey, and many others have made computing powerful and ubiquitous. With a single device that fits in your hand, you can visit places you've never been before, share your thoughts with millions, send money to another continent, and create music, poetry, and more. You can change the world, whether you're a technical genius or not. By using computing, anyone is capable of bringing to life incredible ideas that can benefit all of us.

With this in mind, we are shifting the focus of our live programs from big names to big ideas. These ideas could be about anything—art, space exploration, genomics, the environment. The common thread is that computing plays a role in the imagination and execution of these ideas. For example, in 2017, we hosted Jean Claude Zenklusen, director of the National Cancer Institute's Cancer Genome Atlas. He shared how computing allows scientists to understand the genetic codes of different forms of cancer. Jason Matheny, director of the intelligence community's science and research arm IARPA, talked about why agencies like the FBI and CIA are working on quantum computing projects to identify national security threats. And Mary Lou Jepsen, a former Google [x] and Facebook Oculus executive, shared how her personal battle with a brain tumor inspired an enduring interest in medical imaging. She is now working on a wearable, affordable system called Openwater that could replace the expensive MRI machines common in today's hospitals. By presenting the stories behind these big ideas, we hope to inspire audiences around the world to see the creative power of technology as part of their own journey.

CHM is uniquely positioned to tell stories. With a large and rich collection and an outstanding curatorial team, we are experts on preserving and analyzing the history of technology's transformative impact. We hope to share this knowledge with you through our events by bringing Museum voices to our stage as moderators, incorporating clips from our oral history collection, and displaying artifacts in our auditorium to establish our event content as part of a broader history. For example, at our event featuring Twitter and Square CEO Jack Dorsey, we set up a display that included a point-of-sale system developed for McDonalds in the early 1970s to supplement our conversation on payments systems. At a panel discussion on artificial intelligence in September 2017, we featured a sound bite from AI pioneer Ed Feigenbaum to spark a discussion about how

Live programming is inspiring audiences with new ways to connect computer history to today's technology-driven world. Through conversations about engineering emotional intelligence or changing the way we buy and sell products, the Museum's live programming is a testament to the power of technology when combined with human creativity.

PRESENTING NEW FRIDAY NIGHTS @CHM PROGRAMMING

BY LAUREN MIYAMOTO
MANAGING PRODUCER, CHM LIVE

Experimentation may be as important to new ideas as inspiration. For CHM Live, Friday Nights @CHM is a testing ground to try out new event formats, experiment with production details, attract new audiences, and establish new partnerships.

Like CHM Live, Friday night programming explores a wide range of subjects and mixes history with the present. We have examined topics from the history of graphic design to Africa's growing tech community via documentary screenings, sometimes followed by discussions with the filmmakers. We hosted the Silicon Valley Science Fiction Short Film Festival, developed by curator Chris Garcia. In addition to a display of science fiction–related artifacts from our collection, visitors enjoyed two hours of science fiction short films from around the world.

In October 2017, we also hosted our first-ever "science slam" with IBM Research, which drew an audience of more than 300 people. This event model, already popular in Europe, provides scientists an opportunity to talk about their work in a casual, easily accessible way. Over the course of 5–10 minutes, each of the five participating researchers shared stories about their backgrounds and explained what motivates them to do their work.

As CHM Live programming grows and changes, so does the need for experimentation. In 2018, look for unexpected, exciting, and unusual events on Friday Nights @CHM.

Friday Nights @CHM allows the Museum to experiment with new types of programming and formats, including science slams and film festivals.

studying human behavior can help scientists develop AI systems. In 2017 alone, we have showcased medical computers, vintage video game consoles, code-breaking machines, and much more.

The search for these big ideas is a Museum-wide effort. The speakers on our stage and even the moderator's questions reflect feedback from across the Museum community, from curators to trustees to audience members. We find inspiration from a wide variety of media, including traditional sources like book publishers and industry magazines as well as Twitter, tech bloggers, and events like the TED conference series.

As our live programs are intended to inspire anyone and everyone, we are launching new efforts to expand the reach of our content. We started streaming our events in real time via Facebook Live in January 2017, pushing our shows to a global audience. We also post a video of the entire show to our YouTube channel days after the live program and publish regular recaps featuring short clips of these events on the Museum's blog and Medium channel. We continue to work with KQED Radio and CSPAN to impact the Bay Area, but aspire to partner with new media outlets and institutions to expand our reach globally.

Look for continued growth of our programming efforts in 2018. We plan to bring you a total of 24 events in collaboration with the Museum's Exponential Center, Center for Software History, Internet History Program, and our soon-to-be-opened Education Center. We will be exploring a wide range of topics including the rise and fall of Minitel, how code can reinforce racism, and what the future of quantum computing could look like. And finally, we aim to start working on new content offerings—such as podcasts and video series—based on our events.

Fascinating stories worthy of preservation have emerged from technology. However, it is the human creativity and imagination from which these stories stem—the big ideas—that can inspire. This is what makes programming a crucial part of the Museum's strategy and future. Bob Noyce, Steve Jobs, and Jack Dorsey found their inspiration. We hope our live programming helps audiences find theirs.

CHM Live events are made possible by contributions from Museum donors and members. For more information on CHM Live, please visit computerhistory.org/chmlive.

BEHIND THE GRAPHIC ART OF CHM LIVE: CATCHING UP WITH JENNIFER ALEXANDER

BY CHANEL LLOREN
ASSOCIATE PRODUCER, CHM LIVE

WITH JENNIFER DE LA CRUZ
DIRECTOR OF BRAND & MARKETING COMMUNICATIONS

A blank sheet of paper might intimidate some, but not Jennifer Alexander, the Museum's director of operations and resident graphic designer. Alexander is responsible for conveying the Museum's brand through visuals, from building signage to eye-catching CHM Live graphics. For each CHM Live event, Alexander creates original designs, combining disparate elements like text, imagery, and icons into a harmonious composition that graphically expresses the program's theme.

Alexander's process always begins the same, with a blank sheet of unlined, white paper. Here, she lets her imagination play, as she develops the concept for each show. This original concept remains the same, though the elements may change slightly once she recreates them in Adobe Photoshop and Illustrator. Alexander's event graphics find their way everywhere, from program covers to show posters to the CHM Live stage. While speakers like Square CEO Jack Dorsey and Google Cloud's Diane Greene discuss their latest ventures, Alexander's elegant, modern creations are on display, representing the Museum and CHM Live brands.

Alexander finds her inspiration in everyday moments, seeing the extraordinary in seemingly ordinary objects, from buildings to shop windows to billboards. "The most powerful images," she says, "convey a message. They tell a story."

Jennifer Alexander is the woman behind the CHM Live look. She creates fresh designs that graphically convey the concept for each event.

MASS APPEAL: CHM COLLECTIONS EXHIBIT CULTURE, ART & DESIGN

BY KAREN KROSLOWITZ
DIRECTOR OF COLLECTIONS

Drawing attention at the Design Museum in Helsinki, Finland, (above) and London (below) are artifacts loaned by the Computer History Museum: a 1939 HP oscillator, Steve Wozniak's "blue box," and an Apple-1.

TOP: COURTESY OF THE DESIGN MUSEUM IN HELSINKI / BOTTOM: COURTESY OF PAUL CONNOLLY

An iconic MITS Altair 8800 was loaned to the Center for the Arts at Stanford University.

In 2014, when I received the request from the Gerald R. Ford Presidential Museum for a loan of the Sperry Mk 14 mod 8 gunsight, I didn't consider it out of the ordinary. Museums loan artifacts to each other all the time and CHM has loaned artifacts to other computer, science, and technology museums since its inception. Outgoing loans are just one of the many fundamental ways that museums make artifacts accessible to broader audiences. But how exciting that one of CHM's artifacts would soon be displayed in a *presidential* museum!

The overlap between the Ford Presidential Museum's curatorial interests and CHM's own collecting scope was logical: the gunsight was to be featured in an exhibition commemorating the 100-year history of United States military aircraft carriers and the recent christening of the *USS Gerald R. Ford* (CVN-78). Learning that a web search for "gunsights" led their registrar to our online catalog was deeply satisfying. CHM's efforts to publish its catalog records online were proving useful to other museums, as well as to computer enthusiasts, students, academic researchers, and to many others.

As the web searches continued, the requests became more intriguing. In 2015 the Victoria & Albert Museum in London contacted CHM. The V&A is the world's leading museum of art and design, known for its magnificent architecture, its opulent collections, and its outstanding exhibitions of some of the world's most rare and unique art and artifacts. The V&A is a gold standard by which other museums measure their own successes. To celebrate the counterculture of the 1960s, the V&A was planning a major exhibition, *You Say You Want a Revolution: Records & Rebels 1966–1970*. The groundbreaking HP 9100A calculator from CHM's collection would demonstrate the upstart attitudes and innovations surrounding personal computing. This traveling exhibition can be seen at Milan's Fabbrica del Vapore (The Steam Factory) over the winter and was featured previously at the Montreal Museum of Fine Arts in the fall of 2017.

"We have an encyclopedic collection with an important decorative arts and design collection from the Renaissance to present day," noted Montreal Museum of Fine Arts curator Diane Charbonneau. "The objects come from different fields of making … design-based, craft-based, artist-based, and architect-based. As for showing computers in our galleries, we do so on a regular basis since we have [them] in our collection."

I'd known that new art and media museums were collecting computers too, although I'd previously understood the primary interest was to maintain the computers as tools to exhibit computer graphics, animation, and media-based artworks. And yet, it now seemed those museums were inquiring about CHM artifacts to draw attention to the symbiosis between computing, on art, design, and popular culture.

For example, one of Harold Cohen's "turtle" drawing instruments and film clips became the central storytellers in *Art is Science II* at the Karuizawa New Art Museum in Nagano, Japan. Supporting the idea that artificial intelligence can have a creative side, curator Kanoko Kikuchi said, "Harold Cohen's invention AARON is so important to the histories of AI and art, and we want art lovers in Japan and from Asian countries visiting Karuizawa to know AARON. It might be possible to include computers [in future exhibitions] because in the expressions of contemporary art, many artists use computers like a paint brush as a useful tool."

Does the inclusion of computers as artifacts in exhibitions come as a surprise to visitors of art and design museums? Across the San Francisco Bay, the Berkeley Art Museum & Pacific Film Archive (BAM/PFA) spotlighted one of CHM's three Community Memory terminals and printouts for their 2017 *Hippie Modernism* show. University of California, Berkeley professor and guest curator Greg Castillo described, "For the *Hippie Modernism* exhibition, I wanted to address the misconception that the counterculture was intrinsically anti-technology by exploring connections to the counterculture. Since Berkeley's Community Memory was the hippie cyberculture project *par excellence*, we featured it. For most [visitors] the notion that digital social networking was invented by a group of Bay Area hippies in 1973 came as a shock."

A stone's throw from CHM, the Cantor Center for the Arts at Stanford University exhibited *Creativity on the Line: Design for the Corporate World, 1950–1975*, which told the story of mid-century modern design and innovators. Featured was a MITS Altair 8800, the first commercially successful personal computer

Evidence that the hippie-influenced counterculture was not anti-technology, a mother and child visit a Community Memory terminal at a San Francisco Bay Area community center in ca. 1989.

designed around the Intel 8080 microprocessor by Ed Roberts, founder and president of MITS.

And just north, the iconic red Olivetti Valentine typewriter has been seen by hundreds of thousands of travelers at SFO Museum's *Typewriter: An Innovation in Writing* exhibit. Its curator Daniel Calderon explained, "Recent interest by collectors, writers, and other museums sparked our interest in pursuing a typewriter exhibition. While searching for the iconic Olivetti Valentine, we found a wonderful, red example using the Computer History Museum's online database. Typewriters are a foundational component of computer history. I'm certain we will include typewriters and computers in future exhibits, as they have contributed to our communication and popular culture in a massive way."

Halfway 'round the world, curator Justin McGuirk of London's prestigious Design Museum shared similar thoughts when he requested numerous artifacts for *California: Designing Freedom*. McGuirk noted, "We were very keen to do an exhibition about contemporary Californian design … and technology is absolutely central to that story. From personal computers to laptops to smartphones and social media platforms, California has developed whole new genres of design and had an enormous impact on contemporary life."

CHM provided the majority of iconic computing artifacts and prototypes for the Make What You Want section of the Design Museum's exhibition, including an Osborne IA, an Apple Mac, a Xerox Star, Steve Wozniak's "blue box," a Slate mockup by Alan Kay, a Palm V PDA, and Pagemaker software, along with an Apple-1 on loan to CHM by brothers Ian and Colin Lynch Smith. *California: Designing Freedom* traveled to the Design Museum in Helsinki and will be hosted by the Stedelijk Museum 's-Hertogenbosch, outside Rotterdam in spring 2018. Has the inclusion of computers been surprising to Design Museum visitors? McGuirk replied, "I think it was perhaps a surprise for people to see some of the newer pieces of technology in the show [which] makes them aware of the cultural significance of objects that they currently own."

Looking back on our recent past it's easy to see the incredible influence computing has had on the ways in which we create and live today. Wherever computing has had an influence or impact—which is globally and often in unseen ways—CHM's historical artifacts are storytellers. That is no surprise at all. But don't be surprised if you spot one in an exhibition far, far away.

All quotes were obtained by the author via email for this article.

Collections operations are made possible by contributions from Museum donors and members. For more information on Collections, please visit computerhistory.org/collections.

GRANT WRAP-UP: PROCESSING PROJECT MAKES AVAILABLE 26 CHM COLLECTIONS

BY SARA LOTT
SENIOR ARCHIVES MANAGER

In June 2017, after two and a half years of work, the Museum completed its largest grant-funded processing project to date. In 2014 CHM was one of only 19 institutions selected to receive a Cataloging Hidden Special Collections and Archives grant from the Andrew W. Mellon Foundation, administered by the Council on Library and Information Resources. CHM received $274,560 to minimally process and make publicly available 26 of the Museum's most valuable but hidden collections.

The collections, totaling 1,944 linear feet of material and ranging in date from 1945 to 1988, document the Information Age in the United States and its ongoing impact on society and include records and personal papers from corporations, CEOs, computer science luminaries, female entrepreneurs and inventors, and enthusiastic collectors.

Sixty percent of the material in the project was the Digital Equipment Corporation (DEC) Records. At 1,238 linear feet of text and still and moving images, the DEC Records are the largest and most complete record of DEC in existence, with material from 1947 through 2002. The DEC records took two full-time archivists and nine volunteers 5,000 hours over the course of 14 months to process.

Each of the 26 processed collections has a finding aid available through the Museum's catalog and the Online Archive of California. Additionally, a brief record is available through OCLC WorldCat. As a result of the project 24,351 catalog records were added to the online catalog and the number of researchers visiting the archive is up, with FY2017 marking the most researchers to date.

This ca. 1965 photograph of two Digital Equipment Corporation technicians drilling holes into printed circuit boards was included in the Museum's Cataloging Hidden Special Collections and Archives grant.

COLLECTION OF THE COMPUTER HISTORY MUSEUM, 102755967

DOCUMENTING THE STORIES OF OUR FELLOWS

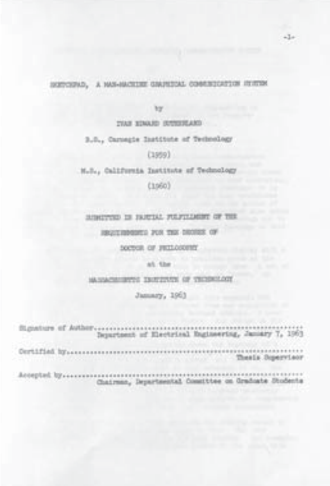
BY DAG SPICER
SENIOR CURATOR

For over four decades, CHM's annual Fellow Awards have publicly recognized leading contributors to computing. These Fellows have shaped the world we live in by applying the power of computing to industry, education, government, science and engineering, and, of course, our personal lives. As we recognize these remarkable people in the public sphere, the Museum also independently collects voluminous materials about each new Fellow to build a mini-archive of their life and contributions. Such materials typically include personal papers, books, lecture notes, ephemera, recordings, software (especially source code), publications, and correspondence.

Taking its inspiration from anthropologist Clifford Geertz, CHM seeks to create *thick histories* of these unique individuals through an ambitious program of collecting seminal documents and personal papers, as well as conducting extensive oral histories. A thick history of a computer pioneer's life's work is one that explores and explains not only the facts of their life and accomplishments, but also the context of their discovery and invention, such that the history becomes meaningful to an outsider or nonexpert many years from now. This becomes even more important with each passing year as the original context of discovery recedes ever further into the mists of time.

A thick history might include, for example, not only the seminal technical papers underlying an invention, but commercial products built using that knowledge, advertising materials, price lists, marketing plans, TV and radio ads, and so on. The idea is to provide a 360-degree view of our Fellows and their contributions. Two recent examples of such mini-archives are the papers and donations of CHM Fellows Gene Amdhal (102658196) and Harry Huskey (102726107).

With its team of curators, media professionals, and archivists, the Museum is preserving the accomplishments of its Fellows with the long view in mind: how will people 100 years from now understand our accomplishments? It is up to us to preserve and make available the materials that can be used in answering not only the *what* but also the *how* and *why* of an invention or discovery.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SKETCHPAD, A MAN-MACHINE GRAPHICAL COMMUNICATION SYSTEM

by

IVAN EDWARD SUTHERLAND

B.S., Carnegie Institute of Technology

(1959)

M.S., California Institute of Technology

(1960)

SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

January, 1963

Signature of Author......................................
Department of Electrical Engineering, January 7, 1963

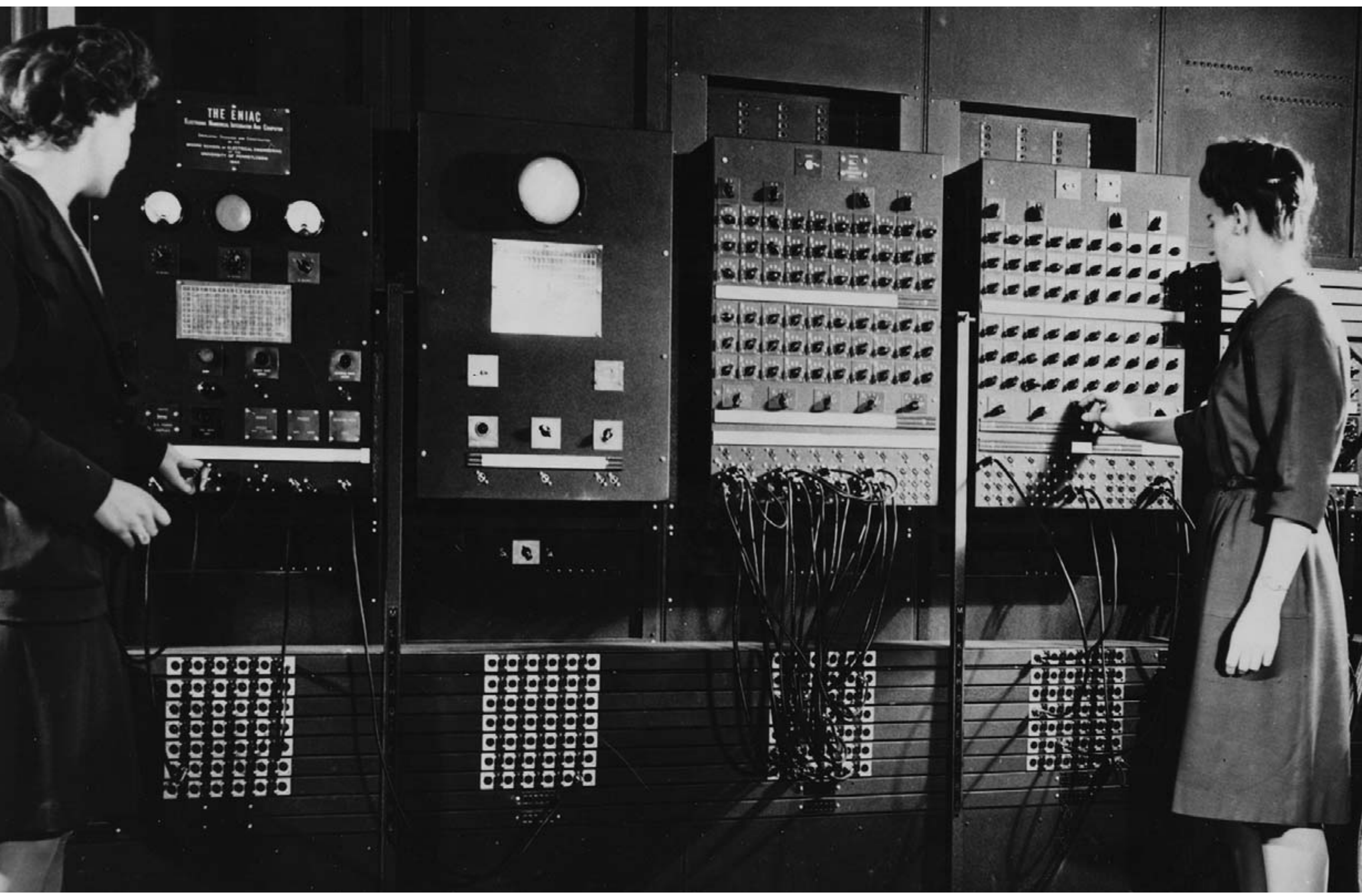
Certified by......................................
Thesis Supervisor

Accepted by......................................
Chairman, Departmental Committee on Graduate Students

Cover page from the famous PhD dissertation by 2005 CHM Fellow Ivan Sutherland detailing his Sketchpad system, an advanced computer-aided design program written at MIT in 1963.

This ungainly device by 2005 CHM Fellow Ivan Sutherland was probably the first head-mounted stereoscopic display (1968), giving the wearer the illusion of being in a 3-D scene. A sophisticated external computer controlled the system.

Jean J. Bartik (left, née Betty Jean Jennings) and Frances V. Spencer (right, née Frances V. Bilas) at work ca. 1946 on the ENIAC's master programmer unit.

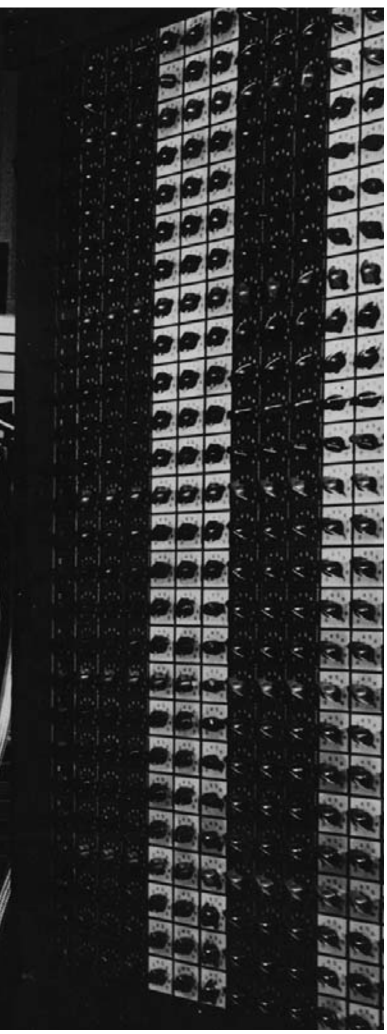


COLLECTION OF THE COMPUTER HISTORY MUSEUM, 102649733

CENTERS

BEYOND INCLUSION: GAPS, GLITCHES & IMAGINATIVE FAILURE IN COMPUTING

BY DAVID C. BROCK
DIRECTOR, CENTER FOR SOFTWARE HISTORY



Software history—like all history of technology—is the story of choices. It is the interweaving of narratives about how some people have shaped the material world in service or in pursuit of some intention or another; of how they and others have used the resulting objects, systems, and practices; and about how this making and using impinges, or not, on the lives of still others. These choices go beyond relatively tangible matters like which features should be included in a software release, or if facial recognition systems should be used in your local supermarket. There are also choices of imagination: Who gets included in envisioning new technological developments, and who is left out. Who is part of the pictured makers and users, and who isn't.

Historians, and other scholars and analysts, study these choices and the cultural and technical factors that condition them. The choices that make up the history of computing are interested, intentional. Intentionality is action for something, and that something is an imagined outcome: profitability, performance, social good, what have you. This essential imagining—that sometimes constitutes what my friend and colleague Patrick McCray calls *visioneering*—is also a framing of who should be included as makers, workers, owners, users, and the otherwise affected. And because the history of computing is the story of the choices made by real people, their essential imaginings are conditioned by their time, place, and experiences. It is for this reason that the imaginings of the history of computing are subject to gaps and glitches, to failures of the imagination, to deficits of consideration for others. As these gaps, glitches, and failures shape our actions, they have very real ramifications for technologies and people's lives.

For many other aspects of society and culture, scholars, public intellectuals, and activists have used Kimberlé Williams Crenshaw's concept of "intersectionality" to focus on just these sorts of gaps, glitches, and failures. While they are areas of nonexistence in imaginings and understandings, they are all too real as lived experiences of people. Professor Crenshaw's work on intersectionality has focused on the ways that social systems of discrimination and oppression around particular identities—notably racism, sexism, and classism—overlap and compound in the lives of real people, say lower-income African-American women, while the experiences and problems confronting real people from their intersecting identities are absent from most widely shared understandings and conceptions of society. Following Crenshaw, other theorists and activists have explored these gaps, glitches, and failures around other identities that are implicated in systems of discrimination, such as sexuality, gender identity, nationality and geography, and disability.

While our contemporary civic discourse is dominated by the very real and vital issue of diversity and inclusion in computing, the concept of intersectionality urges us to also look beyond inclusion. The question of diversity and inclusion in who can and does become a computing maker and user is critical, but it nevertheless is a question firmly about computing constituted as it is, rather than as it could be. The concept of intersectionality asks us to surface and look directly at today's gaps, glitches, and failures in order to imagine different futures for different people.

Recently, the Center for Software History hosted and helped organize a major gather-

Top: Dr. Halcyon Lawrence, a technical communications scholar, speaking at the Museum. Her talk on "accent bias" in speech recognition can be viewed on our YouTube channel.

Bottom: Dr. Grace Hopper ca. 1961 in front of UNIVAC tape drives, holding a programming manual for COBOL, in which she played a key role in creating.

ing of researchers looking at the story of computing from the angles of history, media studies, anthropology, game studies, software studies, and more: *Command Lines: Software, Power, and Performance*. The conference was a meeting of the Society for the History of Technology's Special Interest Group for Computing, Information, and Society (SIGCIS), one of the primary meeting grounds for the diverse international community of researchers studying computing's past. Many presentations at *Command Lines* exposed and examined just these gaps, glitches, and failures around intersecting identities and what they revealed about the bounds within which computing has been imagined.

Halcyon Lawrence of the Georgia Institute of Technology examined the complex ramifications of "accent bias" in speech recognition technologies like Siri, Cortada, and Alexa for those with Caribbean accents living both inside and outside of the Caribbean. Safiya Noble of the University of Southern California introduced her notion of African-American "technigrationists," early adopters of technologies like video game systems, mobile telephones, and two-way pagers in the 1980s and 1990s who were integral to the proliferation of new digital technologies. Maddison Whitman of Purdue University used the notion of "glitches" in the ways that social media posts can be tagged and discovered by both casual users and in automated data "scraping" by social scientists and marketers. For example, Tumblr does not allow tags that are used below some threshold to be searched or discovered, such as those associated with sexual minorities, thereby helping to maintain their invisibility. Many other of the presentations engaged with these kinds of issues and may be viewed on the Museum's YouTube channel.

As important as are these examinations of gaps, glitches, and failures, the problem of discrimination in computing is pressing and profound. On every facet of difference, every ground of identity, computing—that is, the academic, commercial, military, government, and nonprofit communities associated with fostering, developing, and using computing—does not reflect the larger world. There are too few women. There are too few people of color. There are too few LGBTQIA+ people. There are too few disabled people. Age, geography, and sociocultural class are far too narrowly represented.

Why? Increasingly, the answer is seen to be culture. There is nothing about gender, race, sexuality, disability, age, geography, or class that has any purchase on an individual's given potential to thrive in any of the diverse roles within computing. Rather, it is culture—widespread, consistent social practices and behaviors—that shapes an individual's access to experiences relevant to participation in computing, their imaginings of their selves and futures, the exclusionary actions of others, and, critically, the experience of belonging or of indifference, even of hostility, in classrooms, clubs, labs, and offices.

History is one of our most important tools for understanding culture. History can also be intensely personal. With our oral history efforts—creating open access video recordings and published transcripts of the life and career histories of contributors to computing—the Center for Software History is focused on capturing the direct accounts of diverse individuals. Through fostering explorations of computing's cultures in the near and distant pasts, the Center for Software History hopes that rich and powerful understandings of the connection between diversity and culture in computing will be developed and used for addressing the problems of the present.

The Center for Software History is made possible by contributions from Museum donors and members. For more information on the Center for Software History, please visit computerhistory.org/softwarehistory.

IF DISCRIMINATION, THEN BRANCH: ANN HARDY'S CONTRIBUTIONS TO COMPUTING

BY DAVID C. BROCK
DIRECTOR, CENTER FOR SOFTWARE HISTORY

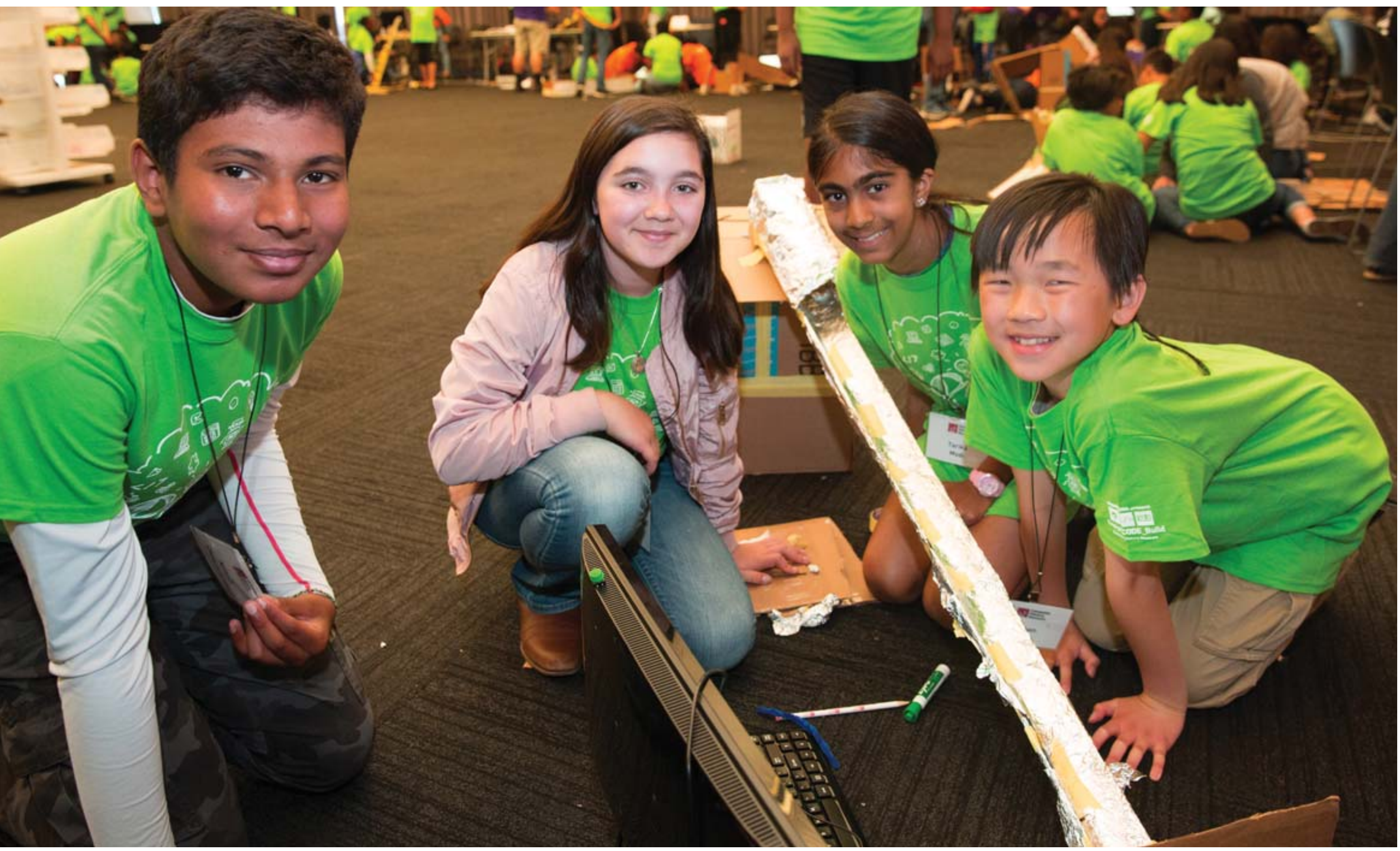
In the realm of software, a "branch" is a computer instruction that causes a shift from the default pattern of activity to a different sequence of actions, a different way of moving ahead if you will. For Ann Hardy, a pioneer in timesharing software and business, her contributions to computing—detailed in her recent oral history with the Center for Software History—were achieved through repeated, creative branching in the face of sexist discrimination. A serious challenge came in the early 1950s as an undergraduate: Despite her interest, she was not allowed to major in chemistry. That was for men only. Hardy branched. The physical therapy major allowed her to take all of the chemistry and technical classes she wanted.

In the mid-1950s, at the suggestion of a childhood friend and fellow mathematics lover, Hardy stopped by IBM's offices at 57th and Madison Avenue in Manhattan and took a computer programming aptitude test. Passing with flying colors, she took a six-week course and aced the final exam. The top 10 percent of the class was promised a job in sales, the pinnacle of IBM, but upper management eventually decided this could not apply to women. Hardy branched. She became an IBM programmer instead, making important contributions to the software for the Stretch supercomputer. Stretch led to a job at the Lawrence Livermore National Laboratory, where Hardy first experienced the then novel timesharing approach to computing. Thrilled by the possibilities of interactive computing, in 1966 she convinced a pioneering startup in the field, Tymshare, to hire her to write their timesharing operating system. They did. To learn about further branchings by Ann Hardy in her rise to an executive at Tymshare and then to a cofounder of a secure-computing firm, read her oral history on the CHM website or watch her oral history on our YouTube channel.

Ann Hardy pictured in the mid-1950s when she began her career in software.

COURTESY OF ANN HARDY

Design_Code_Build students use the engineering design process to solve tech challenges and meet inspiring tech industry "rock stars" such as mechanical engineer Camille Eddy.



EDUCATION

CREATING A CULTURE OF LEARNING AT CHM

BY LAUREN SILVER
VICE PRESIDENT OF EDUCATION

Museums have always been recognized as educational institutions, though their educational goals and the means by which they accomplish these have changed over time. Far from the staid, intimidating edifices of the past, today's museums are lively, interactive places, welcoming visitors of all ages and offering a wide range of options to explore, both in person and, increasingly, online. As with other nonschool "informal" settings, the learning that happens in museums is sometimes referred to as "free choice" or "inquiry-based": it is voluntary and flexible, arising from individuals' varying interests, questions, motivations, and learning preferences, rather than from a prescribed curriculum or the need to pass a standardized test. And, since individuals are infinitely diverse, museums face the challenge of making their content accessible and meaningful in infinitely diverse ways.

This challenge is also an opportunity, allowing museums to experiment with ways of providing information and promoting learning. Here at CHM, we are undergoing something of a revolution as we embrace this opportunity. Education has been part of our long-term vision since the days of the Computer Museum in Boston. (Who can forget the *Walk-through Computer*?!) However, it remained somewhat discrete from what we traditionally viewed as our primary mission: that of preserving and presenting historical artifacts and narratives. Our collective understanding of education—both what it is and who it is for—was also quite limited until the development and launch of *Revolution: The First 2000 Years of Computing* in 2011.

Revolution was our first large-scale exhibition created explicitly to allow for multiple points of entry into the stories we wanted to tell. Vice President of Collections and Exhibitions Kirsten Tashev and her team made use of all of our assets, including but not limited to historical artifacts, to design an experience that would allow visitors to choose not only what they wanted to learn, but how. After opening, we commissioned an evaluation, for which we collected information from people diverse in age, technical expertise, and many other characteristics. Results told us that visitors did indeed make use of the exhibition in different ways, depending on their interests and preferences. And no matter how they approached it, a majority used words such as "educational," "informative," "fascinating," and "fun" to describe their experience. Moreover, a follow-up study three months later indicated that people retained both the information and the sense of enjoyment they had gotten from their visit. Clearly, it had a significant impact.

Since that time, we have focused on deepening our impact and expanding our educational footprint. Starting from a foundation of public tours and a few interactive workshops for K–12 students, we have created a vast array of programs and resources designed to expand the Museum's reach and diversify our audiences, paying special attention to those who are underrepresented in tech and may have limited access to CHM and to STEM learning. We now have a solid team of full- and part-time professional educators. We have a corps of volunteers and interns who are trained in best practices for informal education and who significantly enrich the visitor experience. And we have strong partnerships with teachers, community leaders, museum colleagues, tech innovators, and education scholars throughout the Bay Area and the US. Each year, CHM education programs serve more and

Top: The CHM Education team displays the concept model for the Education Center, designed to support interactive learning, creativity, collaboration, and accessibility.

Bottom: Learning how a computer works: inside the *Walk-through Computer* at the Computer Museum in Boston, 1990.

Docent Bud Warashina leads an interactive discussion about the Apollo Guidance Computer during a tour of *Revolution*.

more individuals, groups, and families; over 12,500 people participated during our 2017 fiscal year alone.

Underlying this growth, and perhaps even more important than numbers alone, is a significant shift toward what I would call an educational mindset: an internal culture that recognizes and supports learning at every level and sees it as a shared responsibility, well beyond traditional education programs. Both the Museum's Exponential Center and the Center for Software History, for example, cite education as one of their foundational principles and develop their collections, exhibitions, and events with educational objectives in mind. The CHM Live team assesses the success of their programs in part by considering audience questions as evidence of attendees' understanding of and interest in presenters' content. And our Marketing and Development teams have articulated forward-looking plans that position education as core to our institutional values and one of our top strategic priorities.

While a commitment to learning is important for any serious museum, it is especially so for CHM, with our content and its unique place in society and history. Computing is an ever-evolving subject. It also risks being an arcane one, reserved for engineers or those with a highly technical bent. Our increasingly technologized global community, however, depends on an informed public, able to think broadly about the impact and implications of technology on our world and our lives, now and in the future.

So what does all this portend for CHM's own future? One of the most visible effects will be our new Education Center. Designed to support varied approaches to teaching and learning, it will provide opportunities that complement and build on experiences available elsewhere in the Museum. In contrast to exhibitions, which often impel visitors to keep moving in order to see the many artifacts and stories we have on display, the center will encourage people to slow down. Hands-on activities will allow visitors to take time—to dig deeper into ideas or investigate artifacts at their own pace, often in collaboration with others. Importantly, we also see the Education Center as an opportunity for staff learning, with space and support to experiment with new programs, modes of presentation, collaborative partnerships, and methods of evaluation and assessment.

Increasingly, we will also see programs and initiatives that consider social and cultural issues in computing—issues that affect not only who creates technology, but also who has access to it and how it gets used. Questions of equity and inclusion are particularly relevant in the context of education, where full participation in the global economy, including basic schooling and career skill development, is more and more dependent on technology. We are committed not only to including these as topics for exploration in our programs, but also to ensuring widespread access to the learning opportunities they provide. Teams throughout the Museum are collaborating on projects such as exhibitions, oral histories, and workshops about gender and computing; live events exploring technology's effects on brain development and learning; and expanding resources for non-English speakers.

Our growing culture of learning, both internally and externally, represents a profound change for CHM. By embracing education in everything we do, we are redefining what a museum can and should be in the 21st century, how it can engage minds around the world, and how it can use history as a platform to understand the past, contextualize the present, and look ahead to the future. We have taken on a big subject, at perhaps the most transformational time in human history, and our impact as a collecting, exhibiting, and, yes, educating institution will be substantial for decades to come.

Educational programming is made possible by contributions from Museum donors and members. For more information on Education, please visit computerhistory.org/education.

HANDS-ON LEARNING IN NEW EDUCATION CENTER

BY EMILY ROUTMAN
INTERPRETIVE PLANNER

The Education Center will offer hands-on activities for all ages to enjoy, from adults to elementary school-age kids. The Computer (De)construction Station is one example. Think you need to be tech-savvy to take a computer apart and put it back together? Here, just about anyone will be able to dismantle and reassemble a real server—a large networking computer that's designed to be easy to service. To make sure everyone can succeed, we've added visual clues, and for those who want more guidance, detailed instructions are available. This is a chance for even nontechies to see and handle all the different components of a computer, from fans and heat sinks to CPUs and memory cards, and learn how they fit together and operate as a system.

Developing these kinds of interactive exhibits entails considerable prototyping and user testing, and there will always be new ones in the pipeline. As a result, there's a good chance you'll find not just finished exhibits but also works in progress. We're exploring new territory and creating new ways to engage visitors. In the process of creating new learning experiences, we're also learning ourselves. It's all part of the Museum's emerging recognition that education is at the core of everything we do.

Interactive exhibits in the new Education Center will let visitors get hands-on with real computer technology. Testing prototype versions is an essential part of the development process.

EMPOWERING EDUCATORS THROUGH DESIGN_CODE_BUILD

BY STEPHANIE CORRIGAN
MANAGER OF SCHOOL & TEACHER PROGRAMS

Technology plays an integral role in our daily lives, one that will only grow over time. At CHM, we want all visitors to see themselves in the story of computing, its past and its future, and to feel confident exploring, experimenting, and engaging with technology. This not only includes students but teachers as well!

At our annual Educators' Broadcom Presents Edition of Design_Code_Build (DCB), we work to connect educators with resources and ideas for incorporating computer science and computer history into their classrooms. Participants explore Raspberry Pi computers, discover stories in CHM's exhibitions, and connect with other educators who are eager to share resources, insights, and experiences. The goal is for educators to leave with ideas they can use immediately as well as the skills and connections they need to keep exploring and building on what they learned.

Integrating technology into the classroom can be challenging, especially for those without a background in technology. Discovering, vetting, and learning to use new resources can be intimidating and expensive. But there are also many educators eager to learn, try, share, and collaborate. Through the DCB Educators' Edition, CHM aims to facilitate this growing network, helping teachers discover new ways to empower themselves and their students.

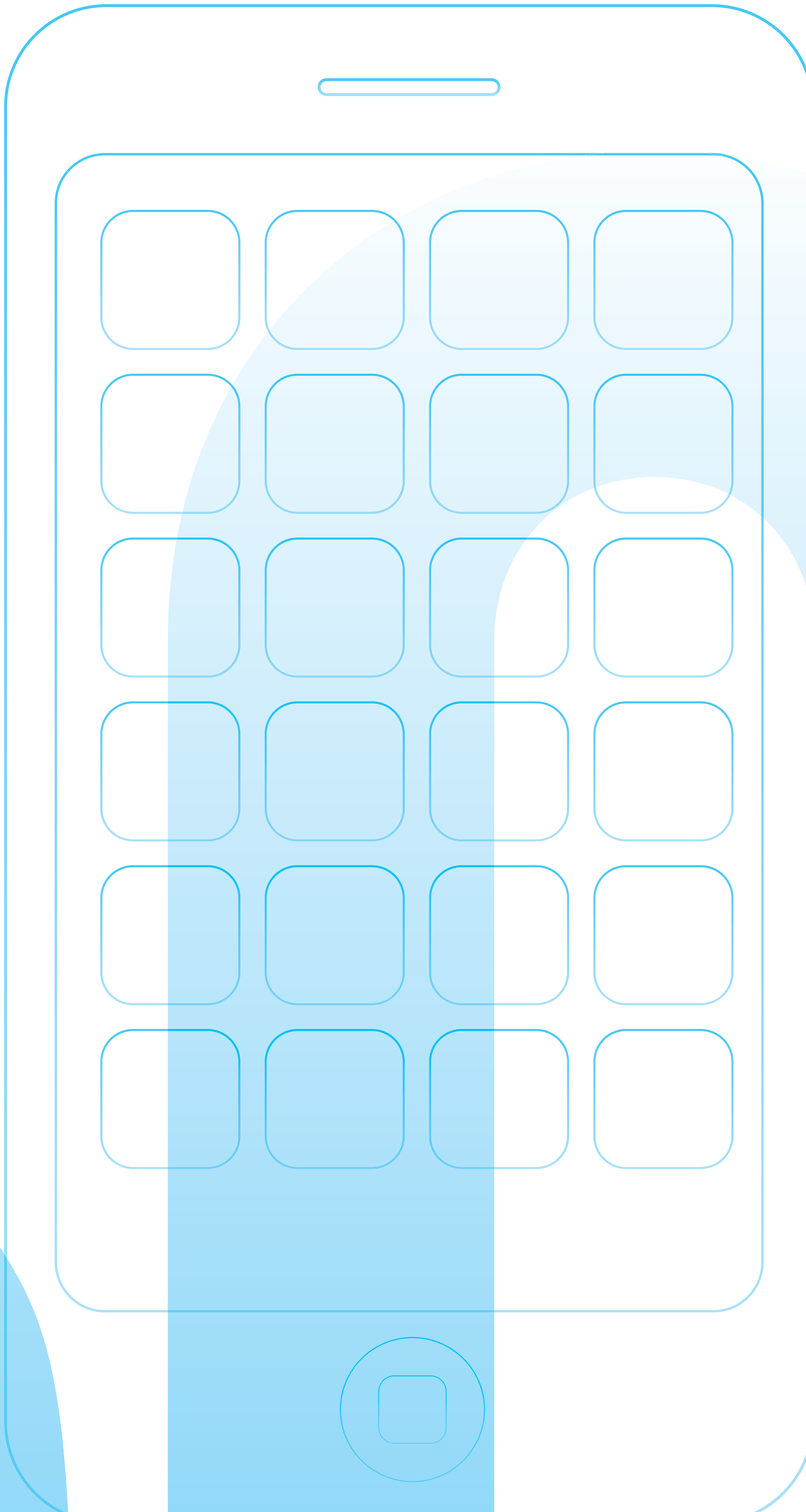
At the Design_Code_Build Educators' Edition, educators discover new resources, share ideas, and build their confidence using technology in the classroom.

ON JANUARY 9, 2007, STEVE JOBS ANNOUNCED THREE NEW PRODUCTS—

a widescreen iPod, a revolutionary phone, and a "breakthrough internet communications device." Of course, iPhone was all three. It was a risky challenge to the dominant mobile companies of the time—most of them outside of Silicon Valley.

Ten years after Jobs' electric announcement, iPhone and its imitators have transformed not just mobile devices but how we use computers. Along the way, it made Apple the world's most valuable publicly traded company and has, through Apple's App Store, catalyzed a trillion-dollar app economy with more than three billion users.

But iPhone's success was far from assured. As part of the iPhone 360 Project at the Computer History Museum (CHM), this selection of articles reveals insights and an array of perspectives on the device:



About iPhone 360

The iPhone 360 explores the story of iPhone, from its prehistory, inception, and launch, to its evolution and impact. Coinciding with the 10th anniversary year of the iPhone launch in 2007, iPhone 360 includes integrated initiatives across the Computer History Museum to create new collections of artifacts and oral histories, scholarly research and insights, dynamic events, feature exhibit, and educational content and curriculum.

The iPhone 360 Project is part of the Exponential Center 360 series focused on transformational companies and products that have changed the world through technology innovation, economic value creation and social impact.

HOW THE iPHONE TOOK OFF

BY MARC WEBER
CURATORIAL DIRECTOR,
INTERNET HISTORY PROGRAM

In early 2007 Steve Jobs unveiled the iPhone as a risky challenge to established smartphone makers, most in other regions. Surprising skeptics, iPhone snapped back the center of the next great trend in computing—mobile—back to Silicon Valley. It would make Apple the world's richest public company.

The iPhone didn't really do anything other phones or handhelds hadn't before. It was clumsy to enter text on and not especially fast, and it initially cost $500. It left out other core smartphone amenities, from ergonomics to decent battery life.

But looking at raw ingredients is only part of the story. It's how you combine them that counts, and presentation matters. Jobs' pet project brought everything together in a package that would change the look, feel, and business model of every smartphone—and tablet—on earth. It would go on to challenge the web and even the personal computer.

TIMELINE

COMPILED BY DAG SPICER
SENIOR CURATOR

This timeline features some of the technologies and products absorbed—or spawned—by iPhone and its competitors.

Compass (200 BCE)
The first compass is believed to have been invented in China as early as the Han Dynasty. Compasses are built into smartphones and used in maps.

Telegraph (1840s)
People once spoke of the telegraph as "the nervous system of the planet." Radio telegraphs in the 1910s pioneered wireless data.

Telephone (1877)
The telephone brought the human voice across great distances.

Payphone (1889)
People on the go often carried spare change for the ubiquitous payphone, a common feature of the American urban landscape until cell phones arrived.

Sony Walkman (1979)
The first mass-produced portable music player let people listen to music on the go.

Digital camera (1991)
Kodak's DCS-100 was one of the earliest cameras to use a digital image sensor, now common in all cameras and most phones.

Apple Newton (1993)
Based on the low-power ARM processor, the Newton was an ambitious personal digital assistant with built-in handwriting recognition. It was also Jony Ive's first design for Apple.

IBM Simon (1994)
The world's first smartphone had only screen-based keys, like the later iPhone. It had contacts, email, games, and fax but no web browser.

i-mode mobile web (1999)
Japan's i-mode (internet mode) phones brought the mobile web to tens of millions, with shopping, maps, mobile payment, and more.

Symbian smartphones (ca. 2001)
Symbian, based on the Psion organizer, was the leading global smartphone OS before iPhone. Blackberry and Treo smartphones were important in North America.

iPod (2001)
Precursor to the iPhone, it allowed users to keep "1,000 songs in your pocket." Songs could soon be purchased from the iTunes store, which opened in April 2003.

iPhone (2007)
Steve Jobs announced iPhone as a "revolutionary product that changes everything." He proudly showed off multitouch, full internet browsing capabilities, widescreen iTunes, and a variety of features.

App Store (2008)
Ushering in an entirely new method of buying software, the Apple App Store provided a curated—and censored—collection of software for iOS.

Angry Birds (2009)
As of 2017, this game had been downloaded over 3 billion times from the Apple App Store. The App Store today has over 140 billion downloads.

What made the original iPhone take off? Millions of words have been written in answer to that question. Besides the fanatically honed artistry of iPhone's design, from software to packaging, here are five specifics:

Screen-forward: A gamble that what people really wanted was the biggest, flattest, crispest screen they could cram into their pockets or purse—even if that meant giving up real keys and buttons.

Fingers: Clumsy for selecting text, but made for pinching and zooming.

Browsing, browsing, browsing: The first thing you do with that big screen.

Multimedia: Not just a camera and cute headphones, but full-screen software to manage your content right on the phone.

Maps: Big, touchable, and soon indispensable. They almost got left out of the original iPhone!

It didn't hurt that mobile networks had recently gotten fast enough to support full-featured web browsing. Nor that Jobs was still at the height of his powers.

Almost Left Behind

By 2006 it was clear to most people in computing that the future was mobile. The cell phone was on its way to becoming the most common electronic device on earth, with over 2.7 billion users.[1] Yet it was almost equally clear that the main events wouldn't happen in Silicon Valley, or even the United States.

Since 1999 Japan had been connected to everything from mobile maps to online shopping with its own version of the mobile web, i-mode. When it came to the small but explosively growing smartphone market, the European Symbian operating system—for which Nokia was a key partner—seemed most likely to succeed. The profitable business smartphone market belonged to Canada's secure, easy-to-type-on Blackberry.

The only local contender was the Palm Treo, based on the sleek, user-friendly Palm operating system that had made the original PalmPilot a wild success. But Palm's rocky business history had limited its influence.

None of this was helped by the fact that US cell phone usage—and networks—lagged years behind other countries and were split into two competing standards (GSM and CDMA).

For a region whose identity was so tied to innovation, it was a smarting blow. During the dot-com bubble the PalmPilot raised hopes that the Valley's business magic could work for mobile as it had for the personal computer and the web. But it proved a brief exception to the Valley's 20-year mobile losing streak—Apple's own failed Newton, GO/Eo, General Magic, the Danger Sidekick, and more.

The iPhone didn't start as a phone. In the early 2000s, the user interface team stumbled across a multitouch pointing device. Could using your fingers to pinch, scroll, and zoom be the basis for a completely new kind of user interface? This turned into a project to make a tablet computer. But galvanized by the success of the iPod, some began to wonder if the new interface could even let a phone-size screen browse full web pages. …

Jobs gave the green light, and they literally taped off a corner of the prototype tablet screen to make it phone-size. But progress was slow, and a parallel project to combine a simpler "feature" phone with an iPod threatened to pull ahead. At a certain point Jobs told the tablet-phone team to hurry up or else. They got the message, and the rest would be mobile history.

Tiny Interfaces

The physical user interface for most computers—a keyboard with text above it—has been set since the typewriter in the late 19th century. But without room for full-size text display or keyboards, handhelds have no such baseline. Each family of products must figure out its own solution to a fearsome user interface problem: how do you get meaningful information in and out of a device small enough to snuggle in a pocket?

It's been 40 years since the electronic calculator began sprouting ancillary features and birthed the handheld computer. In that time, it seems like every possible interface trick has been tried, from the stylus to voice recognition to slide-out keyboards. All are compromises. But the most successful products have turned compromises into selling points, beating out general-purpose handhelds like the Psion or Apple's Newton. The winning trick has been to optimize tiny interfaces for particular functions.

For instance, RIM's email-based Blackberry sacrificed screen space for a thumb-size QWERTY keyboard plus navigation buttons. The earlier stylus-based PalmPilot managed a biggish screen, but by forcing users to learn a simplified script the software could successfully recognize.[2] By the mid-2000s, Palm Treos and other smartphones had adopted a thumb keyboard for entering text but retained a stylus for sketching or precise selection. The combo worked well for entering information but restricted screen space. This was one reason mobile browsing never took off on the first major generation of smartphones.

Another way to sidestep interface limitations is by managing expectations—make your device an accessory to the personal computer, not a potential replacement. The PalmPilot became the mobile incarnation of your calendar, to-do list, and address book; the Blackberry, your hand-held email program.

iPhone started as an accessory too. But instead of emphasizing input with keyboards and styli, the iPhone was a lean, mean browsing machine. The physical design said it all—a literal sheet of glass, as unadorned as the broken-off corner of the tablet computer it came from.

Besides maximizing screen space, the minimalism of that design answered something deep within Jobs' aesthetic, like the barely there vegan diet he fed his physical body. (Had iPhone happened in the curvy, colorful exuberance of his earlier iMac phase, the device in your pocket might look different).

Jobs also disdained the stylus—he famously said we have 10 of them. Direct touch returned adults to both the joys and frustrations of finger painting. The final combinations had a dissonant beauty, at once formal and sensual: using the sensitive pads of your fingers to caress some of the most manufactured substances around—shiny glass, steel, and plastic.

In the zero-sum world of mobile interfaces, these design choices came at a cost for input. No stylus meant no sketching or handwriting, or even easy text selection. Bringing up the iPhone's virtual keyboard covered nearly half the screen. Typing remained slower and more error-prone than on physical keys. As a side effect, it also massively increased visual distraction. Unlike either physical keyboards or styli where you can easily do text entry "blind," soft keys wrench your gaze downward. That adds up, since writing is 5–10 times slower than reading.

Some critics felt its minimalism made the iPhone into the cyber equivalent of high heels. You could still walk, but form topped function. Yet that ignored just how

Most early handhelds sported tiny keys that reduced even touch typists to hunt-and-peck. In the mid-1990s, effective handwriting recognition from Palm—and then the two-thumb keyboards popularized by RIM, like the one shown here—offered relief.

The PalmPilot was the first handheld computer to break into the mass market. Jeff Hawkins tested his early ideas with this model, using a chopstick for a stylus.

good the interface was for its preferred purpose. The big screen and multitouch made it ideal for navigating information on full-size web pages, documents, and images. Along with faster networks, this was the magic key that fully unlocked the mobile web.

The first iPhone didn't have native apps. Those came a year later, in an about-face that both spawned an unbelievably rich ecosystem and threatened to fragment the web itself. Apple's experience with the insanely successful iTunes Store would quickly translate into the App Store. Within a few years came selfies and videos and support for the faster networks of the era (3G). The negotiating tactics Jobs had used to browbeat the music companies into supporting iPod proved effective with the telecom carriers: Apple ended up with unprecedented control over iPhone.

Triumph

When I developed the Mobile Computing gallery for the Museum's permanent *Revolution* exhibition over 2009 and 2010, the smartphone story remained mostly outside Silicon Valley. I interviewed Japanese and Swedish pioneers and went to London to interview the creators of market leader Symbian and the early Psion OS it was based on. The local contingent was represented by the fading Palm Treo and this newish gizmo from Apple. In fact, when the exhibition opened in January 2011, the most recent object in it was the iPhone. (We passed on the newly announced iPad, because its impact was still uncertain.)

The iPhone kept growing. And perhaps most important, Google got involved. By 2012 Android had fully joined the iPhone and iPad's iOS as the new face of mobile. Relatively open and cheap where Apple was closed and expensive, Android played populist Windows to iOS's exclusive Mac. Native apps soon appeared for Android as well, accelerating the wild rush to dream up new services that depended on mobility—from rides to reviews to dating apps.

From 1999, successful smartphones began appearing from companies around the world. Left to right, top to bottom: Blackberry and Treo in North America, Symbian phones in Europe, and i-mode in Japan.

By 2006 it was clear to most people in computing that the future was mobile. … Yet it was almost equally clear that the main events wouldn't happen in Silicon Valley, or even the United States.

Other competitors still had cards left to play. They hoped to imitate the iOS/Android model while addressing one or more of its perceived weaknesses: a focus on consumption over creation; poorly integrated address, calendar, to-do, and notes functions; a lack of secure email, easy syncing, or connectivity with peripherals. They hoped such features might matter even more as mobile followed the iPad from phones to tablets.

But Microsoft's much anticipated Windows Phone 8 fizzled, taking Nokia's smartphone market down with it along with Microsoft's own tablet, the Surface. Windows 8 had been the most credible attempt at general-purpose handhelds and tablets since the days of Apple's Newton. Palm's legacy entered the last stages of dissolution as HP abandoned "iPhone killer" webOS (Palm had sold off its original operating system to Japanese i-mode pioneer Access a couple of years before).[3] The similarly heralded "iPhone killer" Blackberry 10 operating system tanked.[4] The high end of the mobile world now belonged to Apple and Google—and Silicon Valley.

When mammal embryos develop in the womb, they pass through stages that look a bit like older forms—fish, tadpoles, frogs, salamanders, and so on. Computers ecosystems have done much the same.

Cheaper, smaller minicomputers began to threaten hulking mainframes in the 1960s. But not until the early 1970s could they support the kind of command-line operating systems mainframes had pioneered six or seven years before. By the late 1970s, the tiny, cheaper PCs that challenged minis were running their own command-line operating systems, like CP/M. Only much later did they add graphical user interfaces, multitasking, robust memory management, and a host of other features already prototyped on minis.

Today iOS and Android are steadily recreating the functionality of a PC on tablets and—to some extent—phones. The first iPhone had no cut-and-paste and could only run one application at a time, like a PC of 1978. Today's versions still lack proper files and folders. But they can already run many of the same programs as full-blown personal computers. Could an expanded iOS cannibalize Apple's own Macintosh line? It's worth noting the Mac itself was allowed to eat its own predecessor, the Apple II.

But iOS/Android was the first big tech ecosystem that didn't start simple because it had to, given hardware limitations. The first iPhone had more oomph than a Pentium PC of the late 1990s. Windows phones and tablets comfortably manage to bring along a full-featured operating system.

iOS/Android started simple because they started as an OS for a specialized smartphone, not a computer. Its particular flavor of simplicity came because a talented and powerful minimalist thought it was prettiest that way. The full impact of Steve Jobs' choices may lie ahead.

[1] IC Insights, "Worldwide Cellphone Subscriptions Forecast to Exceed Worldwide Population in 2015!" *2015 IC Market Drivers Report*, November 12, 2014, icinsights.com/news/bulletins/Worldwide-Cellphone-Subscriptions-Forecast-To-Exceed-Worldwide-Population-In-2015.

[2] The earlier stylus-based Apple Newton tried to recognize free-form handwriting, but the error rate was so high it was a major factor in the product's failure

[3] Ross Catanzariti, "The Palm Pre Will Be an iPhone Killer," *PC World*, April 2, 2009, pcworld.com/article/162528/the_palm_pre_will_be_an_iphone_killer.html.

[4] "BlackBerry's 'iPhone Killer' For Verizon Turned Into A Flop Report," *Huffington Post Canada*, September 30, 2013, huffingtonpost.ca/2013/09/30/blackberry-iphone-killer-verizon_n_4017227.html.

STACKING THE DECK

CHOICES THAT ENABLED THE iPHONE APP STORE

BY HANSEN HSU
CURATOR, CENTER FOR SOFTWARE HISTORY

After introducing the iPhone in early 2007, Steve Jobs announced that third-party developers could write web applications for it, but not native apps. But by October, Jobs had changed his tune: a full iPhone software development kit (SDK) that let programmers write native iPhone applications would be available next March. Moreover, developers would sell their iPhone apps through an Apple-curated "App Store," to launch July 2008.[1] This touched off another Silicon Valley gold rush, as entrepreneurs and investors raced to create iPhone apps and cash in.[2] The billion-dollar acquisition of Instagram by Facebook in 2012 epitomized this new tech boom.[3] Today, the iOS platform, despite competition from Android, remains the premier platform for mobile app development. Apps are often developed first for iOS, or at least concurrently with other platforms, and developers are more likely to make money with iOS apps. The large library of iPhone apps likewise locks in users; they are unlikely to leave Apple's integrated ecosystem if they have to repurchase their apps on Android. All this secures Apple's user base. Arguably, the App Store has been key to the sustained success of the iPhone and its sister device, the iPad.

Yet all this would have been impossible if Apple had not engineered the iPhone as a platform with easy software development. The App Store opened just a year after the iPhone first shipped, with many apps available. What made this possible?

The answer is that the iPhone SDK, called "Cocoa Touch," was very similar in design to "Cocoa," the development environment for Apple's desktop operating system, Mac OS X. Developers for both platforms used the Objective-C language as well as similar design patterns and wrote code that could be easily shared between a Mac and an iOS app. Mac developers, familiar with Cocoa, needed little learning to pick up iPhone development and were among the first to produce iPhone apps. Cocoa itself was designed to make it easy for a single developer to quickly write fully featured applications, so basing the iPhone on Cocoa would carry over these benefits.

However, as revealed in CHM Live events and oral histories, as well as Brian Merchant's book, using Cocoa was not a foregone conclusion.[4] Several technologies competed to become the iPhone's "software stack," with very different implications for app development. In 2005 this was a competition within Apple between Tony Fadell's hardware division and Scott Forstall's software division.

Fadell had led the team that created the iPod and had created a prototype that was an iPod with phone capability. Dialing was by the iPod's famous click-wheel, evoking a rotary phone. This prototype was ultimately rejected. Nevertheless, Fadell's team had experience with consumer devices and knew how to make software run in the limited hardware of a portable device without draining the battery. They proposed using a stripped down version of Linux for the iPhone's software stack. It wouldn't matter to the end user what operating system the iPhone ran, Fadell's group argued, because they saw the iPhone as an "embedded" device, like the iPod, that users would simply take as is, without the ability to change the software.

Forstall had other plans. Forstall was the head of platform experience, the team responsible for Mac OS X's user interface, applications, and software environment. Forstall and his team saw the iPhone not as an embedded device but as a computer platform, which could run many kinds of software, not just those built by Apple. They were convinced that iPhone's software stack should run a variant of Mac OS X technology, that is, Cocoa. Nitin Ganatra, manager of the iPhone applications team, explained that using Cocoa technologies for the iPhone would allow him to poach employees from other groups within Apple who could quickly get up to speed and write the iPhone's core apps: "We had a lot of engineers who understood [Cocoa]…and we wanted to keep as much of that as familiar as possible so that there wasn't just this huge learning curve for anybody coming in where they wouldn't know how to do anything.…We wanted to make sure that they leveraged that knowledge and only had to learn the new… parts that were unique to development of a phone app."[5]

Forstall's software team eventually won, with iPhone running a variant of Mac OS X. But another decision loomed. Should iPhone's built-in apps be developed using native OS X technologies, like Cocoa, or should they

Former Apple Vice President Scott Forstall discusses creating the iPhone with John Markoff at CHM's iPhone 360 event. Forstall directed the original iPhone's software team.

use web technologies? Mac OS X had a feature called "Dashboard," that held widgets showing information like stocks and weather that were quickly launched on a user's desktop. Widgets were written with web technologies—HTML, CSS, and JavaScript—and used "WebKit," the framework behind Apple's Safari web browser. Since web browsing with Safari was a crucial feature of the iPhone, it was trivial for the iPhone web team to port the Weather and Stocks widgets to the phone. Indeed, the designs of these apps on the original iPhone were the same as their Dashboard widget predecessors. The advantage of WebKit was that many more third-party developers knew JavaScript than Apple's Objective-C language from Cocoa.

However, WebKit had a key disadvantage. Its apps were slower and used more memory. Memory on the iPhone was so scarce that if an app used too much, the OS would kill it.[6] This is still how iOS works today.

Richard Williamson, then manager of the iPhone web team, has his own take on the drawbacks of web apps. His team knew how to write web apps that were lean and fast, but the complexity of web technologies doesn't encourage this, leading most web apps to be bloated and slow. Apple's native Cocoa environment, on the other hand, steers developers in the right direction, making it easier for them to apply best practices.

Eventually a compromise was reached. Apps ported from Dashboard by the web team, like Stocks and Weather, could continue to use WebKit, and would be owned by the web team under Williamson, while most of the other iPhone apps, to be written by Ganatra's apps group, would use a native solution.

Ganatra's engineers, led by Scott Herz, investigated simply bringing OS X's Cocoa to the iPhone but decided it would be better to write a new framework from scratch, which they called "UIKit."[7] UIKit was designed according to the same principles as Cocoa, but with some improvements. UIKit was tailored for multitouch input and in the beginning only contained what was needed to write iPhone's initial apps: a phone-calling app with built-in address book, music player, and email client. All these apps contained lists of text that had to be scrolled at a smooth 60 frames per second and, when tapped by a finger, could drill down to reveal another screen with more detail. This made it a natural component to be shared in the UIKit library by all apps, rather than each having their own implementation. With this strategy, the apps team was able to implement the human interface team's designs and make them butter smooth.[8]

With UIKit, the iPhone had its own native software stack ready to be opened up to third-party developers. When those developers at Apple's Worldwide Developer

Opening in 2008, the App Store transformed iPhone into a mobile platform that launched millions of third-party apps, including Instagram, Snapchat, and Candy Crush.

Forstall and his team saw the iPhone not as an embedded device but as a computer platform, which could run many kinds of software, not just those built by Apple.

Conference (WWDC) got to see the iPhone prerelease, they understood that web apps would be inferior to Apple's native apps. Web apps would probably run slower and would look slightly different, lacking the polished UI of native apps. Web apps would also not have access to the iPhone's sensors, such as its accelerometer, that made possible some of iPhone's coolest features. Ganatra notes that if WebKit wasn't good enough for Apple's own apps, why would third-party developers be satisfied with it?

When Forstall and other executives finally convinced Steve Jobs to allow third-party apps for the iPhone, the infrastructure of UIKit was already in place. Had the decision been made to use the hardware team's Linux stack instead, opening up the iPhone to third-party apps might have taken much longer. Mac developers would not have been able to learn iPhone development so quickly or produce as high-quality applications in as little time. The App Store might not have taken off as it did with as many apps. Competing platforms—not only Android, but also Palm's webOS and Microsoft's Windows Phone—might have had an opportunity to catch up with iPhone. Apple's decision to base iPhone's software on OS X stacked the deck such that, except for Android, these competitors have never caught up.

1 Charles Arthur, *Digital Wars: Apple, Google, Microsoft and the Battle for the Internet*, 2nd ed. (London; Philadelphia: Kogan Page, 2014), 200–201, 212.

2 Jenna Wortham, "The iPhone Gold Rush," *New York Times*, April 5, 2009, sec. Fashion & Style, nytimes.com/2009/04/05/fashion/05iphone.html.

3 Evelyn M. Rusli, "Facebook Buys Instagram for $1 Billion," *New York Times*, April 9, 2012, sec. Dealbook, dealbook.nytimes.com/2012/04/09/facebook-buys-instagram-for-1-billion/.

4 Brian Merchant, *The One Device: The Secret History of the iPhone* (New York, NY: Little, Brown and Company, 2017).

5 Oral history of Nitin Ganatra (part one), interviewed by Hansen Hsu, April 24, 2017.

6 This scheme, called "Jetsam," was proposed by Richard Williamson.

7 Oral history of Nitin Ganatra (part one), April 24, 2017.

8 After the iPhone announcement, but before the iPhone launched, the WebKit-based Clock, Calculator, Weather, and Stocks apps were rewritten in native code by members of the web team for performance. Oral history of Nitin Ganatra, April 24, 2017; oral history of Kenneth Kocienda and Richard Williamson (part two), interviewed by Hansen Hsu and Marc Weber, November 13, 2017; and email correspondence with Scott Goodson, October 13, 2017.

BY MARGUERITE GONG HANCOCK
EXECUTIVE DIRECTOR, EXPONENTIAL CENTER

FROM CALIFORNIA TO

COURTESY OF PHOTOGRAPHER PETER BELANGER

iPHONE IN THE GLOBAL ECONOMY

CHINA AND BEYOND

On January 9, 2007, wearing his trademark jeans and black mock turtleneck, Steve Jobs revealed the iPhone—a device that would "change everything"—to 4,000 people gathered for the annual MacWorld conference in San Francisco, California. Seventy-four days later, Apple announced the sale of its one millionth iPhone, and a decade later, cumulative iPhone sales topped 1.2 billion units.

When it first launched, however, no one could imagine the scale and scope of iPhone's global business and political economic impact. It has powered Apple's meteoric rise to the most valuable public company in the world, upended major industries, and fueled a new software application economy. Perhaps lesser known, iPhone has been a key impetus behind the evolution of Apple's complex supply chain with direct impact on the economy and society of many countries as well as its transformation into a symbol and substance of pressing global political economic issues.

Donning a factory uniform, Tim Cook tweeted a photo with a worker assembling an iPhone during a 2014 visit to the Foxconn factory in Zhengzhou, China.

A Race to the First Trillion-Dollar Company

With iPhone retailing at premium prices, less pricey Android has become the dominant smartphone operating system worldwide, especially in developing economies. But Apple has, thanks to iPhone, consistently captured the lion's share of total smartphone profits. In 2006, iPod and Macs together contributed 78 percent of Apple's $19 billion of revenue. By 2016, iPhone generated 63 percent of revenues which had increased by more than a factor of 10 in 10 years to $216 billion. These days, Apple's revenue is nearly as much as Amazon, Alphabet, and Facebook combined and its market value is more than five times that of General Electric, a traditional blue chip stock. In November 2017, Apple became the first public company to clear a $900 billion market cap and some analysts predicted it would ride on the back of iPhone X sales to become the first $1 trillion company. At the heart of these developments is a global network with direct impact on economic and social life in many countries.

Beyond Apple, the ripple effects of the iPhone and Android smartphone revolution have devastated—and spawned—major companies and industries. PC sales have plummeted and smartphones have eclipsed gaming consoles. *Time* magazine reported that Pokémon GO was downloaded as a smartphone app 750 million times versus Nintendo's Mario lifetime sales of 500 million. Always available digital photos and videos forced Kodak, a 131-year-old film pioneer, to file for bankruptcy in 2012, symbolizing the end of photographic film and standalone cameras for most consumers. Traditional television and movie companies are struggling to compete with new distribution channels and business models of companies like YouTube, Netflix, and Hulu, which deliver a majority of content to viewers on mobile devices. In transportation, Uber, Lyft, and Didi Chuxing have disrupted taxis and personal car ownership—part of the larger gig economy enabled by smartphone functions combined with apps. Apple's App Store created an entire industry around app design and development. In less than a decade, the App Store economy has generated more than one and a half million US jobs and US developers have earned more than $16 billion from App Store sales worldwide. By 2016, the global app economy was valued at $1.3 trillion, generated by purchases from 3.4 billion people. At the heart of these developments is a global network with direct impact on economic and social life in many countries.

Welcome to iPhone City in China

"Designed by Apple in California. Assembled in China." These eight words printed on the back of every iPhone represent Apple's global supply chain and manufacturing ecosystem. Apple manages hundreds of suppliers employing more than 1.6 million people in 20 countries. None is more important than China. It is the country where all of the pieces for iPhone literally come together.

"Great to meet talented people like Zhang Fan, who helps make iPhone 6 in Zhengzhou," Apple CEO Tim Cook tweeted during a factory visit in 2014. Zhang Fan represents one of 350,000 workers employed by Foxconn, one of Apple's main subcontractors, who assemble, test, and package iPhones in nearly 100 production lines housed in dozens of factory sites across more than two square miles for what locals call "iPhone City." Their capacity: up to a mind-boggling half a million iPhones a day. The Zhengzhou factory is emblematic of the complex magnetic forces that both attract and divide Chinese and American players in the global political economy.

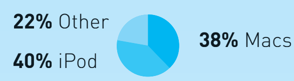
TIM COOK/TWITTER

IMPACT

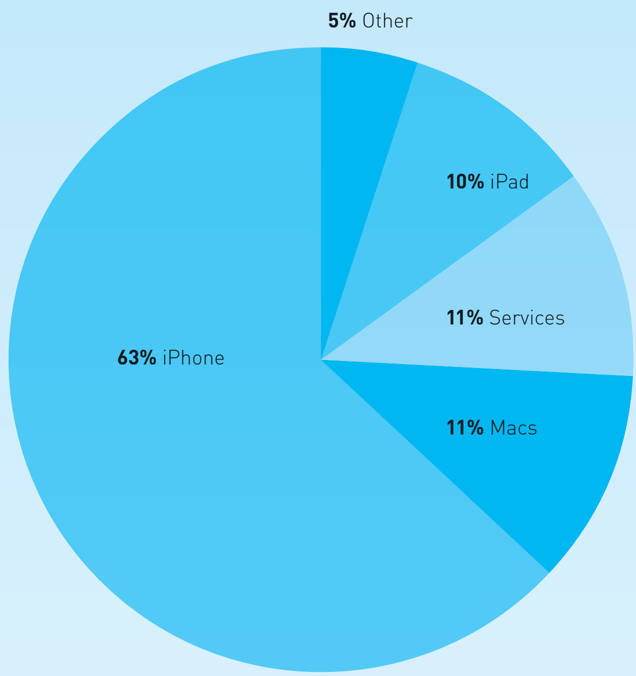
iPhone's impact has rippled across many arenas: it has transformed Apple's revenue, spawned a trillion-dollar app economy, catalyzed a smartphone revolution, and enabled disruption in industries from personal transportation to food delivery.

Apple's revenue by source, before and after the iPhone

2006:
$19B



2016:
$216B



1.2 billion	iPhones sold since 2007 debut
42x	the proportion of data vs. voice for mobile monthly internet traffic in 2017
85	percent of one trillion+ digital photos each year taken on smartphones
1.3 trillion	dollars in revenue of 2016 app economy from purchases by 3.4 billion people
4.8 million	workers for Uber, Instacart, and the on-demand economy enabled by smartphones, compared to 4.7 million workers in IT and IT services

COMPILED BY THE COMPUTER HISTORY MUSEUM

How did Zhengzhou become iPhone City? After the first iPhone rolled out in 2007, Zhengzhou, a rural city of six million in an area bypassed by China's industrialization boom, saw a huge opportunity for development. Government officials doled out $1.5 billion in grants to Foxconn for construction of factories and housing for workers and offered tax exemptions and discounts on power bills. They even created a bonded zone, equipped with customs officials at the factory gate to facilitate iPhone exports, and a newly expanded airport, to help Apple save on export fees and expedite product shipments to overseas markets.

Zhengzhou has an atmosphere of San Francisco in the 19th-century gold rush. Hundreds of thousands of people have migrated to the boomtown city—young migrants seeking job opportunities and better wages and entrepreneurs trying to cash in on the influx of workers. Newcomers have set up restaurants, discos, stores, gambling halls, and skating rinks. But observers, including those commenting on Cook's Twitter feed, have expressed concern about fair employment, economic opportunity, or safe working conditions. Since a string of 14 suicides in 2010 in Foxconn's Shenzhen factory, labor organizations have criticized the firm's long hours, harsh treatment, and limited breaks, leading to worker exhaustion and higher accident rates. Foxconn has introduced changes and Apple reports that among its suppliers there was 97 percent supplier compliance with their 60-hour work week in 2015. However, most workers still seek extra hours to command higher income.

Along with other US tech firms, Apple was named one of "Eight Guardian Warriors" (八大金刚) by state-backed *China Economic Weekly* in 2013.

In May 2017, Apple named Corning, long-time supplier of Gorilla Glass for iPhones, as first recipient of a grant for advanced manufacturing in the US.

COURTESY OF CORNING GORILLA GLASS / OPPOSITE PAGE: *CHINA ECONOMIC WEEKLY* / PAPER.PEOPLE.COM.CN/ZGJJZK/HTML/2013-06/24/CONTENT_1259857.HTM

Is the (Globalization) Honeymoon Over?

With iPhone and Apple's sizable impact on whole cities and industries in China, the firm has become a natural target in the recent backlash against globalization. Following the 2013 published leaks from Edward Snowden about purported US hacking directed at China, a public campaign against US technology firms in China heated up. State-backed *China Economic Weekly* published an issue titled "He's Watching You." The cover image featured a World War II–era US propaganda poster with a head wearing a helmet inscribed with the NSA logo. The article warned of a threat to national security by Apple, Cisco, Google, IBM, Intel, Microsoft, Oracle, and Qualcomm, referring to them as "Eight Guardian Warriors" (八大金刚). This pejorative moniker deliberately echoed a disastrous foreign group from Chinese history—the "Eight-Nation Alliance" (八国联军), which included the US—that invaded and occupied Beijing in 1900, forcing the Empress, Emperor, and high government officials to flee the Imperial Palace.

The Eight Guardian Warriors were decried for "seamlessly infiltrating China" by being deeply entrenched in the hardware and software that make up China's key national information infrastructure, from personal mobile phone communications to business operations to the country's public networks for government, finance, railways, civil aviation, and healthcare. More than just talk, after media began disparaging the "guardian warriors," calling for a "de-Cisco-ization campaign" (去思科化运动), sales of many US tech companies fell dramatically.

Under the leadership of President Xi Jinping, China has emphasized its mission to transform from factory of the world to innovator for the world. The Chinese government is tightening access to its huge market and pressuring Western technology companies to help advance state plans to achieve "indigenous innovation" and "self sufficiency" for "Made in China 2025."

Apple is finding ways to support PRC national priorities by powering 100 percent of its operations in China with renewable energy and partnering to install massive amounts of clean energy sources. In 2017, Apple committed to invest more than $500 million to open four research and development institutes to advance new technologies and "help develop the next generation of entrepreneurs." Despite Apple's efforts to be a careful corporate citizen in China, the company faces continuing headwinds.

Facing Political Pressure in the US

iPhone has also attracted criticism and political pressure at home. While on the campaign trail, now US President Donald Trump promised, "I'm going to get Apple to start making their computers and their iPhones on our land, not in China." While no plans have been announced yet for iPhone manufacturing in the US, in May 2017, Tim Cook launched a new Apple $1 billion fund to invest in advanced manufacturing in the United States, part of a campaign to show how the global tech giant is creating jobs for US workers. The first award: $200 million for Corning, iPhone supplier for Gorilla Glass, the go-to material for smartphone touchscreens.

JOURNEY

While design, development, and marketing are centered in California, Apple orchestrates a complex, cost-effective supply chain with hundreds of suppliers across tens of countries to build and deliver iPhones to customers world-wide.

Follow the journey of an iPhone 7—from design in California, to raw materials sourcing and component manufacturing, to final assembly in China.

	What	Where Made	Company Headquarters
1	iPhone Design: Integrated hardware and software design and engineering	United States	Apple / Cupertino, CA
2	Lithium: A metal used in rechargeable batteries	Chile	
3	Cobalt: Element used in batteries	Congo	
4	Barometer: Determines altitude above sea level	Germany	Bosch / Germany
5	A10: Central microprocessor or "brain"	Taiwan	TSMC / Taiwan
6	RF antenna: Provides connection with cell towers	Taiwan	Qualcomm / San Diego, CA
7	Wi-Fi processor: Sends and receives WiFi signals	Japan	Murata / Japan
8	LCD Display Module: Main phone display	Japan	Japan Display / Japan
9	NAND Storage: Long-term memory for apps, photos, etc.	South Korea	SK Hynix / South Korea
10	Audio processor: Processes sound going in and out of phone	Taiwan	Cirrus Logic / Austin, TX
11	Camera: Cell phone photography	Japan	Sony / Japan
12	Battery: Keeps your cell phone powered up	China	Desay Battery / China
13	GPS: Tracks location of phone	Taiwan	Broadcom / Irvine, CA
14	Final Assembly: Where all the pieces come together	China	Foxconn / Taiwan

COMPILED BY THE COMPUTER HISTORY MUSEUM

The new phones rolled off the line in 2017. On the back were the familiar eight words with a new twist: "Designed by Apple in California. Assembled in India."

Apple Chief Operating Officer Jeff Williams said, "This partnership started 10 years ago with the very first iPhone, and today every customer that buys an iPhone or iPad anywhere in the world touches glass that was developed in America."

Designed by Apple in California. Assembled in India?

Changes in digital technologies and the global business environment are pointing to new challenges and opportunities to come. In 2015, Foxconn announced its intention to transform Zhengzhou's iPhone production and other factories through software and robots. Capable of performing more than 20 tasks,"Foxbots" are already replacing staff in so-called "3-D" jobs—tasks that are deemed dirty, dangerous, and dull. Foxconn's Zhengzhou factory is on track to become fully automated in a few years. While automation may provide initial relief for workers from extreme employment conditions, robots will soon put hundreds of thousands of people out of work. These changes will redefine what iPhone's "Assembled in China" means.

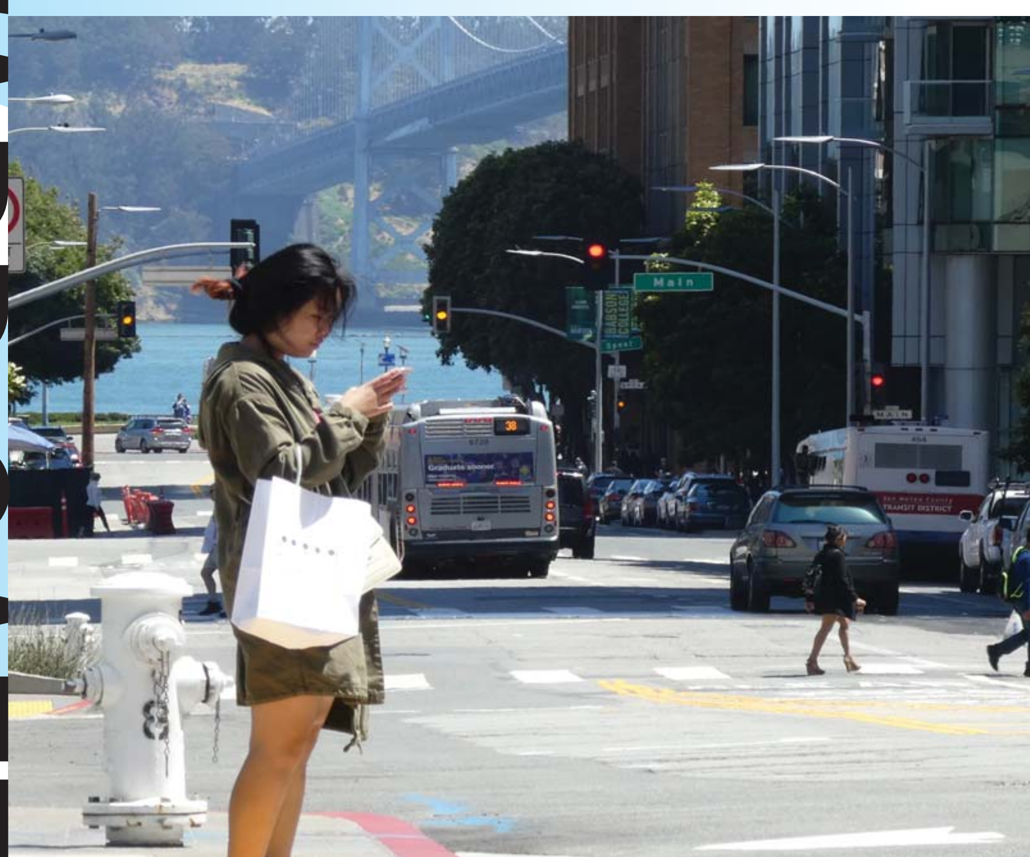
In the near term, iPhone is the key to Apple's future and China remains key to iPhone's future for both manufacturing and market. The relationship is fraught with high-potential rewards and risks and what lies ahead is uncertain. China remains the single largest market for smartphone firms on the planet. For years China's growing middle class has been an engine for Apple's spectacular growth. More recently, Apple revenues saw successive quarters of declines in China. While Chinese brands like Huawei, Oppo, Vivo, and Xiaomi have struggled to gain traction in the US, they all overshadow Apple and Samsung in terms of units sold in China. Local firms are competing fiercely not just on price but also on features, functionality, and fashion. In September 2017, the day before Apple unveiled iPhone X, with prices starting at $999, China's scrappy Xiaomi introduced its "iPhone killer" Mi Mix 2, priced at $500. The battle for smartphone users' hands, eyes, and pocketbooks is stronger than ever.

As sales have lagged in China, Apple has turned its eye increasingly to India, a rapidly growing huge market. Apple has begun assembling its low-priced iPhone SE in southern India's technology hub of Bengaluru. This time, its manufacturing partner is Wistron, a Taiwanese firm and Foxconn competitor. iPhone is opening the next chapter with a fresh combination of manufacturers and consumers. The new phones rolled off the line in 2017. On the back were the familiar eight words with a new twist: "Designed by Apple in California. Assembled in India."

When Jobs announced the iPhone as a device that "changes everything," no one could have predicted the scope and contours of its far-reaching impact and unfolding story. If the journey of iPhone in its first 10 years is any indicator, the next decade for Apple will be full of extraordinary opportunities mixed with competing pressures and unexpected consequences on the global political economic stage.

BY JOHN MARKOFF
HISTORIAN

A DOWNWARD GAZE



Today many of us wander in public with our attention focused on the smartphone in the palm of our hand.

Walking through San Francisco's financial caverns in recent years, I have marveled at the growing fraction of people who wander the streets of my city with their eyes focused downward at the omnipresent and powerful computer in the palm of their hand.

My first reaction is always, "This cannot be the final stage in computer interface!"

In the space of just four short decades we have moved from a computing era in which a relatively small number of mainframe computers were kept, walled off from humans behind glass walls, to an increasingly intimate relationship between humans and machines.

By the end of this year, more than half the adult population of the world will have some kind of smartphone and the line between what is human and what is computer will increasingly begin to blur.

The impending arrival of the next stage of computing raises two pressing questions—how have these machines already changed what it means to be human and how will they transform humanity in the coming decades?

It is not an idle question and it is one that keeps at least some of the inventors of smartphone technology up at night. In a conversation that I had earlier this year at CHM with Tony Fadell, the former Apple Inc. executive who led the hardware design of the first iPhone, he acknowledged that it is something that he thinks about a lot.

"I wake up in cold sweats because I think about that," he told me. "I think about the impact of the creations that I've been involved with and how it has impacted society so dramatically over the last 10 years."

He sees both positive and negative consequences for a technology that he was closely involved in and which is now ubiquitous. "Is it going to be Alexander Graham Bell bringing light to society or did we bring nuclear weapons?"

It is something that concerns me as well. I came of age with an earlier generation of computing. Personal computers were described most eloquently by Steve Jobs as "bicycles for the mind." I have always loved that description. It is evocative of the original ideal as set forth by Douglas Engelbart, the inventor of the computer mouse and hypertext. He believed passionately that computing could be used to augment the human intellect. He saw computing as a ray of hope and a path to solving humanity's challenges.

Now, however, when I cross the train tracks in Palo Alto, the city where I grew up, I see the 24-hour crossing guards who are there to prevent teenage suicides and wonder whether the iPhone isn't also changing our world in darker more fundamental ways.

That is the argument of Jean Twenge, a psychologist who believes that the iPhone has had a debilitating effect on a young generation she dubs "iGen." In her book *iGen: Why Today's Super-Connected Kids Are Growing Up Less Rebellious, More Tolerant, Less Happy—and Completely Unprepared for Adulthood—and What That Means for the Rest of Us*, she cites a raft of statistics that the mobile post-PC era of computing has effectively "destroyed" an entire generation. It has made them more depressed, more suicidal, less individual, and less attentive.

I think about her critique a lot when I consider the possibility that this new generation of computing technology has stolen sleep from today's teenagers, possibly leading to a chain of behaviors whose path is from stress to depression to suicide.

I hasten to note that this is not a proven consequence of the smartphone. At another recent CHM event on the societal impact of the iPhone, my panelists were more sanguine, arguing that the power of the iPhone as a communications tool and its ability to foster virtual communities outweighed its tendency to isolate us from each other.

For example, Judy Wajcman, a London School of Economics sociologist, argued that family and peer pressure to achieve has outweighed any particular technological factor in producing the dysfunction seen in this generation of American teenagers.

However, this debate is clearly just the tip of the iceberg when it comes to identifying the economic and social changes that the iPhone has brought to society. It has, for example, made possible a rapid transformation of the workforce as so-called "talent platforms," harnessing today's workers into the gig economy. Jobs are no longer something that you pursue for an entire career, but rather increasingly granular activities that may last for months, weeks, days, or even hours.

Then there is the question of what the iPhone has done to the delivery and consumption of news—increasingly the fundamental link that connects citizens to their democracy.

It is richly ironic that as a youngster in Palo Alto I delivered papers to the future homes of both Steve Jobs and Larry Page, arguably the two people who did more to change the way news is delivered than anyone else on the planet.

"When we invented the personal computer, we created a new kind of bicycle."

Steve Jobs invented the first personal computer in 1976 with his partner, Steve Wozniak. Today, Steve Jobs is vice chairman of Apple Computer Inc., a $175 million company based in Cupertino, California. Apple Computer has grown to be the leader in personal computing.

What is a personal computer?

Let me answer with the analogy of the bicycle and the condor A few years ago I read a study…I believe it was in Scientific American…about the efficiency of locomotion for various species on the earth, including man. The study determined which species was the most efficient, in terms of getting from point A to point B with the least amount of energy exerted. The condor won. Man made a rather unimpressive showing about 1/3 of the way down the list.

But someone there had the insight to test man riding a bicycle. Man was twice as efficient as the condor! This illustrated man's ability as a tool maker. When man created the bicycle, he created a tool that amplified an inherent ability. That's why I like to compare the personal computer to the bicycle. The Apple personal computer is a 21st century bicycle if you will, because it's a tool that can amplify a certain part of our inherent intelligence. There's a special relationship that develops between one person and one computer that ultimately improves productivity on a personal level.

"There's a special relationship that develops between one person and one computer that improves productivity on a personal level."

Today, most people aren't even aware that the personal computer exists. The challenge of our industry is not only to help people learn about the personal computer; but to make the personal computer so easy to use that, by the end of this decade, it will be as common in our society as the bicycle.

That's one of the reasons I wanted to do this interview. I wanted to explain what a personal computer is, how it can help all of us make better decisions and how it will eventually impact all phases of society…from training dolphins to glaucoma research to growing a more nutritious crop of soybeans.

What's the difference between a personal computer and other computers?

The key difference is that one-on-one relationship between man and machine I was talking about, because the emphasis is on a *personal* interaction.

The whole concept is this: for the same capital equipment cost as a passenger train, you can now buy 1,000 Volkswagens. Think of the large computers (the mainframes and the minis) as the passenger train and the Apple personal computer as the Volkswagen. The Volkswagen isn't as fast or as comfortable as the passenger train. But the VW owners can go where they want, when they want and with whom they want. The VW owners have *personal* control of the machine.

In the 60s and early 70s, it wasn't economically feasible to have the interaction of one person with one computer. Computers were very costly and complicated; 50 people had to share one computer. Back then, you could have the passenger train but not the Volkswagen. But with the advent of microelectronics technology, parts got smaller and denser. Machines got faster. Power requirements went down. Finally, electronic intelligence was affordable. We finally had the chance to invent the personal computer, to invent the "intelligent bicycle."

"When we designed the Apple, we wanted to offer the benefit of a $15,000 computer or a $100,000 time-sharing system with a computer that costs as little as $1,500."

Basically, Steve Wozniak and I invented the Apple because we wanted a personal computer. Not only couldn't we afford the computers that were on the market, those computers were impractical for us to use. We needed a Volkswagen.

People like us were the initial market for the personal computer. After we launched the Apple in 1976, all our friends wanted one. By the time Apple II was on the market in mid-1977, the demand for the personal computer had already begun to skyrocket.

Today, we've sold over 100,000 Apple personal computer systems. That's because Apple recognized this passenger train/Volkswagen relationship about 2 or 3 years before anyone else. When we designed Apple II, we wanted to offer the benefit of a $15,000 computer or a $100,000 time-sharing system with a computer that costs as little as $1,500. Obviously, one of the differences between a personal computer and other computers is price. Another difference is size.

I'd like to use another analogy here: the huge motor and the fractional horsepower motor. When the first motor was invented in the late 1800s, it was only possible to build a large and expensive motor, just like it was with the early computers. Those motors were used to power entire shops, with pulleys and belts running throughout the shops to drive the individual machines scattered within. Only with the advent of the fractional horsepower motor could horsepower be brought *directly* to where it was needed.

With the portable Apple, you could say we invented the first fractional-horsepower computer. The Apple is small enough to go where you need it. You can get the information you need on your desk, in your office, in the lab, the school or the home. In other words, Apple broke down the huge monolithic computer into small, easy to use parts. We made the computer friendly. So, like the fractional horsepower motor distributed horsepower to where it was needed, the personal computer can distribute intelligence to where it's needed. Ultimately, it will be this distribution of intelligence that will *change the way we all make our decisions.*

You've stated that the personal computer can increase productivity on an individual level. How so?

Personal computers will increase productivity because personal computers are tools, not toys. For example, in the last 15 years, there have been only four tools that actually have increased the efficiency of the office worker: the IBM Selectric® typewiter, the calculator, the Xerox machine and the newer, advanced phone systems. Maybe that portable cassette player you're using could be number five. Like all those inventions, the personal computer offers its power to the *individual.*

In the 80s, the personal computer will do as much for the individual as the big computers did for the corporation in the 60s and 70s. Today, Apple's putting the power of computing into the hands of people who might never have had the chance to use it before.

"In the 80s, the personal computer will do as much for the individual as the big computers did for the corporation in the 60s and 70s."

We at Apple call our personal computer a third-wave tool. Toffler, in his latest book, writes that the first wave was the invention of agriculture…made possible by the tools of agriculture. The second wave embraced the tools of the industrial revolution. The personal computer is a third wave tool to help every individual deal with the complexities of modern society.

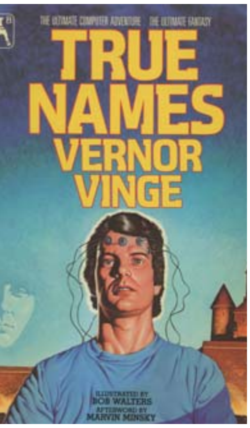
You know, about 10 million bicycles will be sold in America this year alone. When we start thinking of a personal computer as a bicycle, a Volkswagen or a fractional horsepower motor, we start to realize what kind of effect 10 million of these typewriter-size machines is going to have in our own lifetime.

This is part one of a series where Steve Jobs talks about the personal computer, and the effect it will have on society. To find out more about the Apple family of personal computer products, see your Apple dealer. For the name of your nearest computer store, call (800) 538-9696. In California, call (800) 662-9238.

apple® computer

PCs were an example of a technology that augmented human intelligence. Today, smartphones may bind us more closely together, while leaving us relatively mindless.

Tony Fadell, one of the iPhone's inventors, wonders whether he has set loose a privacy nightmare—not unlike the cyberspace of Vernor Vinge's ***True Names.***



By the end of this year, more than half the adult population of the world will have some kind of smartphone and the line between what is human and what is computer will increasingly begin to blur.

I am less concerned about the economic collapse of newspapers—a consequence of the power of the internet to digitize the creation and communication of information—than I am in the power of an intimate computing technology, like the iPhone, to become the principle vehicle for the delivery of "fake news."

There is growing evidence that a disinformation campaign carried out by the Russian government was instrumental in tipping the scales in the 2016 American presidential election. Russian designed software bots disseminated billions of impressions of political opinion that Facebook, Twitter, and Google smartphone users believed were created by other US citizens.

In fact they weren't. Rather they were the product of Russian troll factories bent on secretly reshaping American politics and sowing the seeds of political discord.

We should have seen this coming. In the 1980s, computer scientist and science fiction writer Vernor Vinge explored the question of what would happen in a world with relatively infinite computing power and infinite bandwidth. The result was *True Names*, a novel about the power of anonymity to transform society.

The rise of powerful artificial intelligence technologies that can seamlessly create, tailor, and deliver information to individuals raises questions about human individuality in the face of a global network that is weaving us all together into a new kind of society if not community.

It is increasingly likely that iPhone has insured that we are surrounded by a continuously expanding cloud of algorithms that offer us an infinite variety of advice, from where we should go for Korean BBQ to who we should marry, with little transparency.

The danger, of course, is that this new web will create a form of soft control. Historically, successive computer generations have marked a pendulum-like swing between the centralization and decentralization of technology. Indeed, the Berkeley Free Speech Movement was in part responding to a centralized and computerized bureaucracy and personal computing was a decentralizing force.

Today, is the pendulum swinging backward? For several years it has occurred to me that the biggest concern we face in the ubiquity of the computing technology the iPhone represents is the Borg of *Star Trek*. "Resistance is futile, you will be assimilated" is good science fiction, but it is also the technological trend that people like Tony Fadell are worrying about as the smartphone weaves our society more closely together.

Ironically, it is also not a new concern.

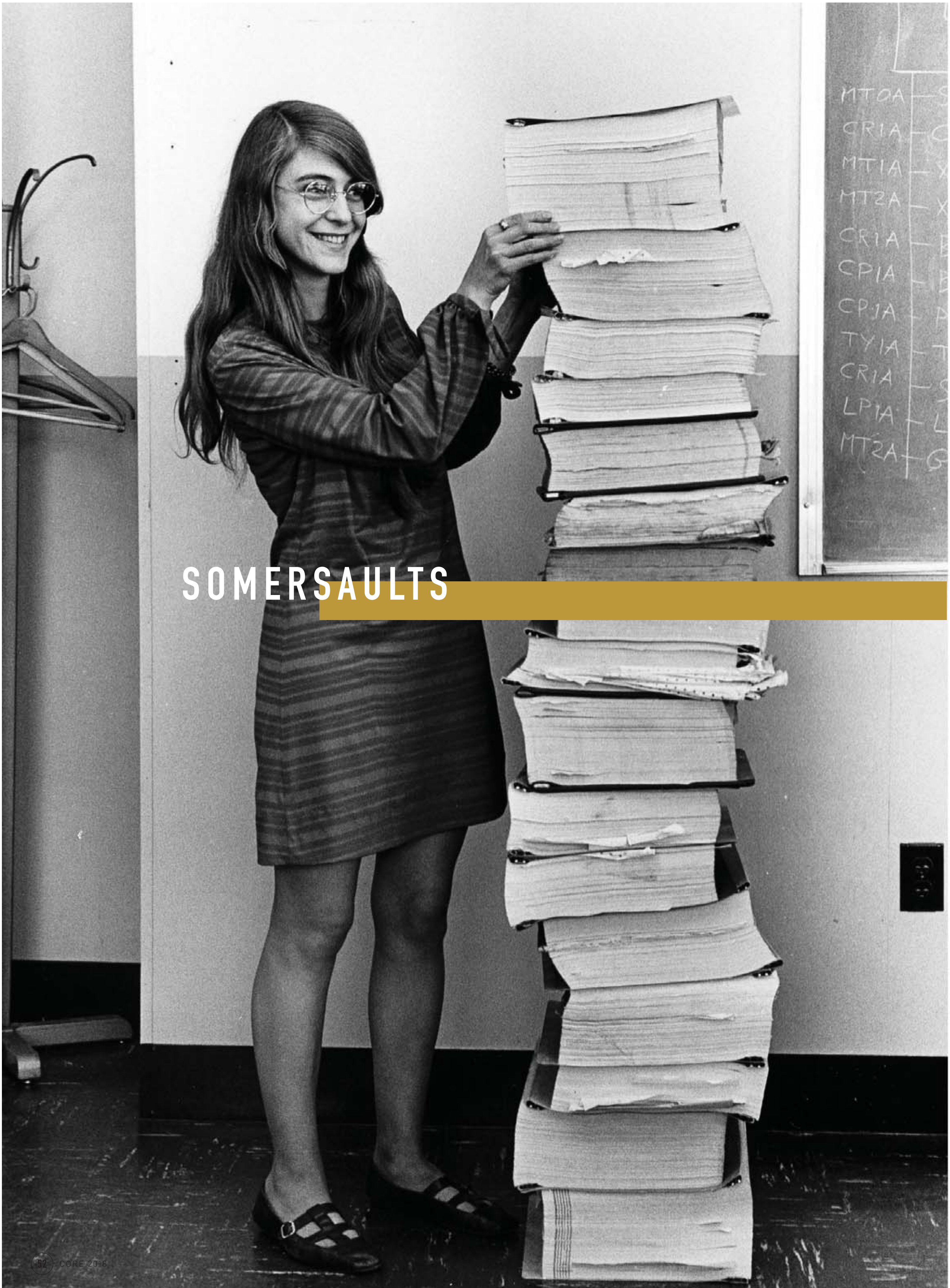
At the dawn of the computing era in the early 1950s, Norbert Wiener, the pioneering cyberneticist and author of *The Human Uses of Human Beings*, issued a similar warning: "When human atoms are knit into an organization in which they are used, not in their full right as responsible human beings, but as cogs and levers and rods, it matters little that their raw material is flesh and blood."

Can we avoid this fate?

I think there is still cause for hope. A number of years ago, I realized that at the dawn of the era of interactive computing in the early 1960s, two laboratories set out independently to invent the future of computing. John McCarthy intended to build a working artificial intelligence system at the Stanford Artificial Intelligence Laboratory on one side of the Stanford University campus, and, on the other side of campus, Doug Engelbart planned to amplify the intelligence of individual humans at what was then the Stanford Research Institute.

That is very much still our choice—whether we design humans into or out of the future. And whichever way the next generation of computer designers lead us, it will be played out in the palm of our hands, on the iPhone.

SOMERSAULTS



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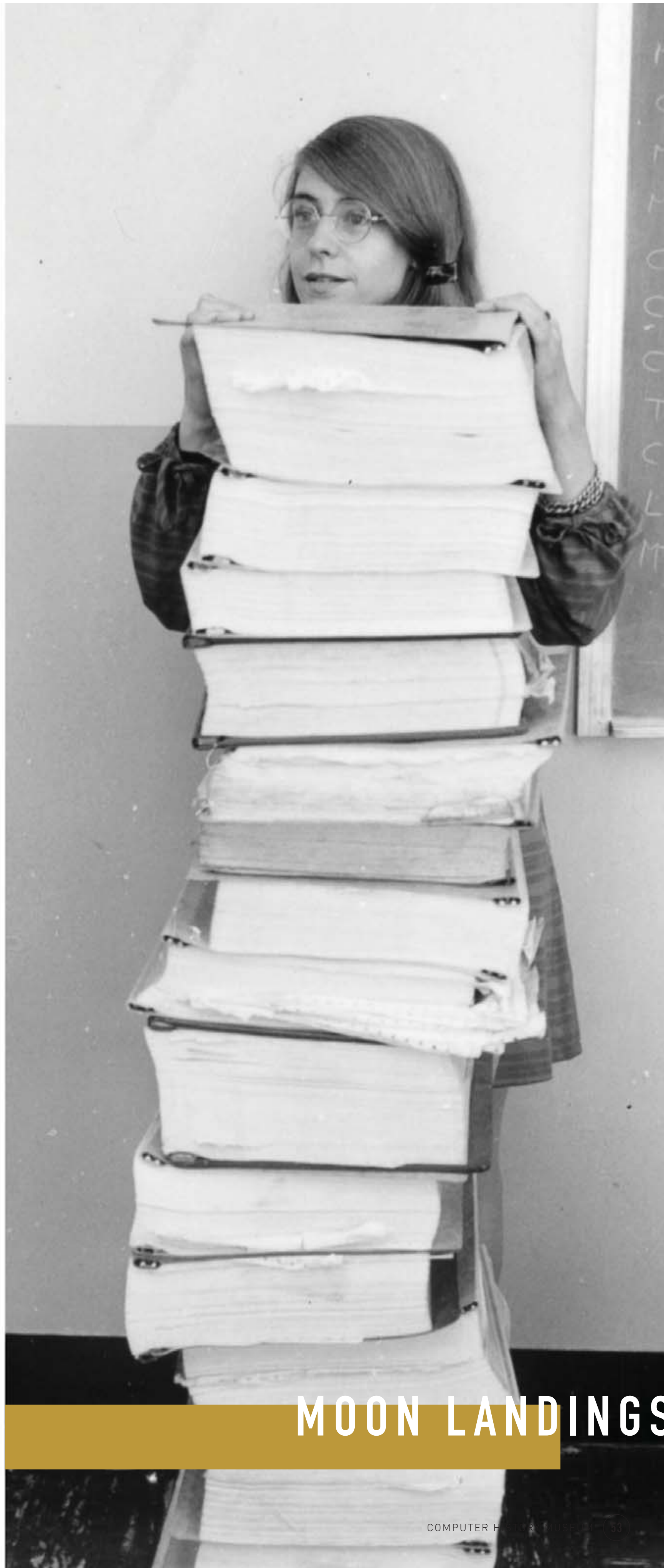
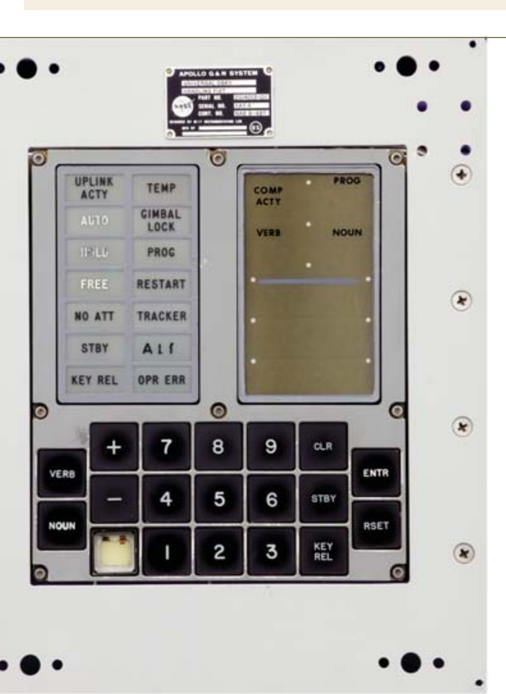


MOON LANDINGS

BY DAVID C. BROCK
DIRECTOR, CENTER FOR SOFTWARE HISTORY

Software pioneer Margaret Hamilton was elected a Fellow of the Museum in 2017 for "her leadership and work on software for DOD and NASA's Apollo space missions and for fundamental contributions to software engineering." In particular, she played a leadership role in the software for the Apollo Guidance Computer, which literally took man to the Moon with Apollo 11.

Excerpted from a recent oral history with the Center for Software History, Hamilton reflects on the all-too-exciting moment of that mission—the moment of landing on the Moon—when the results of her persistence and technical creativity took center stage. In a second selection from the interview, she illustrates the kind of dogged, open-minded problem-solving that she found so important in software-making to her own creative solution to a problem with the physical education requirements of her undergraduate institution, Earlham College.



A prototype input/output module for the Apollo Guidance Computer in the Museum's collection.

On the Apollo 11 Experience

Hamilton: . . . I think it was around 1966, and I don't know what made me think of this, but I started worrying about the astronauts and what-ifs, you know. And somehow it worried me, "What if there's an emergency and they didn't know it?" Because they're just merrily going away, reading the data and putting it in, but what if there's something really major going on and that's it? So I had a meeting with software and hardware people. By software people, at the time, probably, I'm meaning systems people, system designers and everything, and the hardware people. And I wanted to put something in.

Now remember, we have an asynchronous environment, right, with all the software. However, we were not asynchronously communicating with the astronauts, OK? We could send something. They'd see the displays, they'd put something in, but we couldn't interrupt their displays. So what I wanted to do was to interrupt the astronauts to tell them there's an emergency so they'd stop doing what they're doing, OK? So big meeting. And first the hardware guys said, "Can't be done." Remember, I'm still relatively new to this, especially to the hardware. And I said, "Well—" and, also, they all looked at me as a beginner, and I'm not a hardware person, so what do I know, right? *(laughs)*

So, anyway [. . .] they said, "It can't be done," and I said, "Why not?" They said, "Well, first of all, the hardware is not on throughout all the mission," right? And I said, "So, leave it on. Why can't it be left on," right? And then another hardware guy said, "I don't know. We've never left it on that long. It might not work that long," right? So I said, "Well, that's too bad. Maybe we could put it on at times *(laughs)* when there's most likely to be an emergency." They said, "Let us think about this," right? So they came back, maybe a couple of days, and they said, "We've decided to leave the hardware on."

Brock: *(laughs)*

Hamilton: I was so happy that—I mean here these guys are; they're all experts. They all have their egos like everybody does, and the fact that they listened to me and they said, "Hmm, we really could—" because it was a challenge for them, right, and they came back and said, "We'll do it."

Well, then the systems guys came along, "Can't do it." I said, "Why not?" And they said, "Because we've read all these things about parallel processing and what you're trying to do has a real problem because it's no longer async[hronous] now. It's parallel, [. . .] that's a whole parallelism thing going on." So I was really upset. I got through the hardware part. Now, that night I went home and I had to solve it because it mattered to me . . . So I came back with a solution the next day. *(laughs)* And, again, these guys were gurus. I mean all these guys were gurus. They'd been around in this area for a while. And they thought about it and they said, "I think it can be done." And it was something they said had never been done in parallel processing, but I came up with this rudimentary thing . . . the problem was he's [the astronaut] got his normal display and now you put up a priority display. Which one is he answering, you see? And so I came up with the idea of counting to five before he answers.

So Houston—the hardware guys got behind it. They put the stuff into the hardware, and then the Houston guys put it into their manuals, whatever you call them, checklists for the astronauts. They practiced. It was called the five-second display, so it got in all the missions starting from the landing on the Moon, so it's in there for both the LEM and the Command Module in case there's an emergency, whatever it might be. You warn them [the astronauts], you tell them what it is with this display, and they're given a choice. You either go here or there, that kind of thing.

So, anyway, now we go to Apollo *(laughs)* 11 and it's time to land, OK? And … they're going through all the things you go through for landing, and all of the sudden guess what comes up: 1201 and 1202 priority displays telling them there's an emergency. This is just before they land. And here were the things that I had wanted to do was to warn the astronaut when there's an emergency; and 1201 and 1202 means that there were too many things going on in the computer.

One was to do with the tasks, too many tasks trying to get scheduled, and the other was too many jobs based on priority getting scheduled. So it went to a restart and the restart programs were set up to go back to checkpoints, not start the program over again, but go to the last safe place so that it could just pick up and carry on, getting rid of lower priority stuff and just—so that's why it happened more than once. Now Houston knew, they'd seen the 1201 and 1202 before, and the astronaut knew that he had put the switch in a position that had caused extra stuff affecting the computer, and he realized, "Oh, yeah," and he put it back in the right place and they landed.

On Problem-Solving in Software & Life

Brock: The next question is about any life lessons or advice that you'd like to impart to young people, and maybe young people considering a career in doing something technical.

Hamilton: Yeah, you know, I have always found when I've hired people, the combination of the experts and the young kids works best because sometimes the experts can get stuck in a traditional way and the young kids might come out and say, "Why this," right? And I think I've learned along the way from the young kids. But keeping in mind there's old people that are still young kids at heart, OK? They have an open mind.

But I guess, don't be afraid to question things and don't be afraid to ask so-called "stupid" questions. I mean I remember—this is a little off from your question … at Earlham, believe it or not, in order to graduate you had to do a somersault in phys. ed. and I could not do a somersault, and I thought, "I'm not gonna graduate." I haven't passed this, right? And so for years I'd not been able to. I was just afraid of this thing.

And all of the sudden—and I was taking ballet, swimming, and all that—and it hit me: I can do a somersault. I'll do it in the water. *(laughs)* So I passed that physical ed. exam. Well, it's learning to think of solving a problem. If you can't solve it, put it in a different place, you know, and don't be afraid to disagree with the experts. You know, in our company, I'd always say "Never say never, yeah, and never give up." Just because people say it's never gonna work, you know, that doesn't mean you have to give up. And there have been many times when people say things like that and you ignored them and it was a good thing.

For more on Margaret Hamilton, watch http://bit.ly/margaret2017chmfellow, and read computerhistory.org/atchm/2017-chm-fellow-margaret-hamilton/.

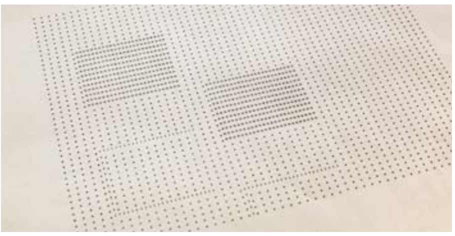
The Oral History Program is made possible by contributions from Museum donors and members. For more information on the Oral History Program, please visit computerhistory.org/collections/oralhistories/.

BY DAG SPICER
SENIOR CURATOR

CRAY INC., CX-1 PERSONAL SUPERCOMPUTER

CHM #: 102741154, X7838.2016
Date: 2008
Donor: Gift of Cray Inc.

Supercomputers have been the lifeblood of high-technology development and advanced scientific research since their first appearance in the 1960s. As they are expensive to purchase and operate, these ultra-fast machines are often shared with many users to make them more cost effective. To bring supercomputing performance to the desktop and to partially eliminate the need to share supercomputer resources with other users, Cray developed the CX-1 "personal supercomputer," a desk-side platform for advanced high-performance computing. The system runs a version of Windows or Linux, and its hardware can be optimized by the user for a wide range of applications.



RICHARD WILLIAMS, ART1 PROGRAM OUTPUT, US

CHM #: 102776170, X8054.2017
Date: 2016
Donor: Gift of Mike Albaugh

Making computer art can be highly techni-cal and early attempts were often created by computer researchers and programmers since few working artists had the required computer skills. In 1970 University of New Mexico computer scientist Richard Williams created a program to allow artists who were computer novices to more easily create art. His ART1 program ran on IBM computers and was used by several well-known artists, most notably Frederick Hammersley. CHM member and docent Mike Albaugh was recently given a copy of the ART1 program and ran it on an operational IBM 1130 (1965), from which this output comes.

ADAM OSBORNE COLLECTION, US

CHM #: X7926.2017
Date: 1975–2009
Donor: Gift of Cynthia Geddes

Adam Osborne was a pioneer in the history of personal computing. The founder of Osborne & Associates, he began selling computer-themed books in the 1970s, as well as attending early Homebrew Computer Club meetings, a legendary group of computer pioneers and hobbyists, many of whom went on to shape Silicon Valley for decades to come. He founded Osborne Computer Corporation in 1980, releasing the Osborne 1 portable computer a year later. The computer's success, based in part on its inclusion of thousands of dollars of software as part of its basic price, led to rapid growth for the company and fame for Osborne. The company failed only four years later due to management issues and Osborne passed away in 2009. His family has donated a large selection of materials to the Museum, including a rare metal-cased Osborne 1 prototype, many of the books published by Osborne & Associates, internal business documentation, and hundreds of photos of Osborne, both the company and the man himself.

DIGITAL EQUIPMENT CORPORATION, DECTALK

CHM #: 102757099, X8003.2017
Date: 1984
Donor: Gift of Bob Blankenship

Speech synthesis has been an area of active research since scientists began working on the problem in the 1960s at Bell Labs. In the 1980s and 1990s, Digital Equipment Corporation became a leader in the field with its DECtalk system. Based largely on the work of MIT scientist Dennis Klatt, DECtalk could read printed text in a number of different voices. DECtalk was used in many applications, including station identification for the National Weather Service, reading patient medical information in emergency rooms, and perhaps most famously, providing a voice for famed theoretical physicist Stephen Hawking.

DONOR PROFILE

FRANKLIN "PITCH" & CATHERINE H. JOHNSON PROVIDE SUPPORT FOR TWO MAJOR INITIATIVES AT THE MUSEUM

BY PAMELA GESME MILLER
ASSOCIATE VICE PRESIDENT OF DEVELOPMENT

When venture capitalist Franklin Pitcher "Pitch" Johnson Jr., founding partner of Asset Management Company, Palo Alto, California, was approached in 2015 about providing major support to help complete the Museum's new *Make Software: Change the World!* exhibition (opened in January 2017) and for the new entrepreneurial and innovation center (now named the *Exponential Center* and launched in June 2016), he did not hesitate because he loves technology, history, and the Museum!

"I believe the Computer History Museum gives us the best opportunity available to understand the past of a society with computers and gives the next generation of citizens an increased ability to shape it, as technology and its uses evolve," says Pitch.

Pitch is a self-described "Midwest boy" who takes pride in the values of speaking his mind, being honest, and helping others. A native of Quincy, Illinois, he grew up focused on track and field. His father, an Olympic hurdler, was the track and field coach (1928–1940) and director of the Drake Relays (1933–1940) at Drake University in Des Moines, Iowa, and later went on to become the track coach (1941–1943) at Stanford University.

Because of an excellent physics teacher at Palo Alto High School, Pitch became interested in technology and attended Stanford, where he took courses in mathematics, physics, and chemistry before graduating with a degree in mechanical engineering. He earned an MBA from Harvard University in 1952 and then served as an aircraft maintenance officer in the US Air Force for two years, during which he married Catherine Holman. From 1954 to 1962, he was an open-hearth trainee and supervisor at the Inland Steel Company's Indiana Harbor Works. Pitch was advised by his superintendent on his first day, "We've had college kids here before—get to know the men on the floor to learn how to make steel." Looking back, Pitch can attribute much of his venture capital success following the principles of this advice.

In 1962, with a combination of savings and family loans, he and a friend, Bill Draper, a former Inland salesman, cofounded the Draper and Johnson Investment Company, an early venture capital firm, in Palo Alto. Together they literally knocked on the doors of newly formed companies to learn about promising new inventions in which they could invest and guide. They "did not think of themselves as pioneers, but it did seem like a good business." Draper and Johnson invested in entrepreneurial opportunities and advised the companies in their early phases. After three years, they sold their portfolio to Sutter Hill Ventures, and in 1967 Pitch launched his own firm, Asset Management Company (AMC).

For over 45 years, AMC has invested in more than 200 tech startups, including Amgen, Biogen, and Tandem. In 2012, AMC became a family office focusing on managing the Johnson family investments and supporting a variety of nonprofit organizations.

Pitch and Cathie raised four children in the Palo Alto home where they have lived since 1967. He has been an active jet pilot, a close follower of track and field, has attended 13 Olympic Games, and served as chair of the San Francisco Opera Association. Pitch also developed and taught a course on venture capital at the Stanford Graduate School of Business for 12 years—it was the first venture capital course taught in a graduate school of business.

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The Computer History Museum is the world's leading institution exploring the history of computing and its ongoing impact on society. The Museum is dedicated to the preservation 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.

The Museum brings computer history to life through large-scale exhibits, an acclaimed speaker series, a dynamic website, docent-led tours, and an award-winning education program.

HOURS

Wed–Sun
10 a.m. to 5 p.m.
(See website for special hours)

CONTACT

Computer History Museum
1401 N. Shoreline Blvd.
Mountain View, CA 94043
info@computerhistory.org
650.810.1010

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