2019

CORE

A Publication of
the Computer
History Museum

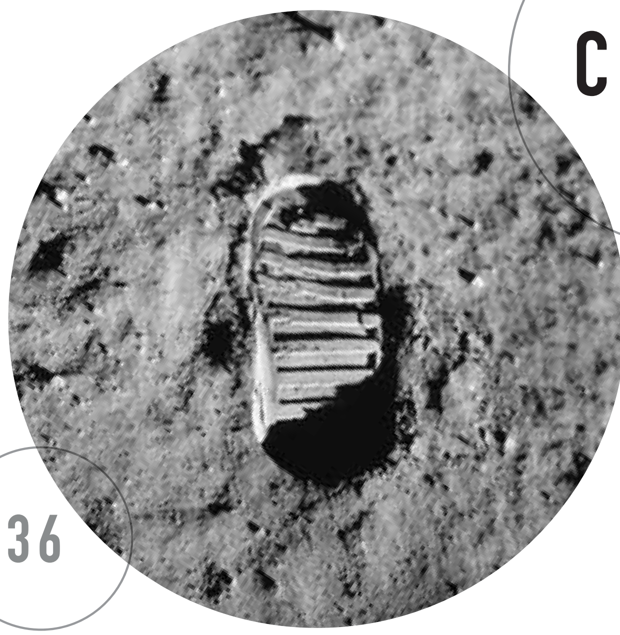
The Moon Landing @50
Collecting Outsider Narratives
A Special Place for Learning About Learning

Cover: The Moon, photographed by the Apollo 10 crew on May 24, 1969. Two months later, the Apollo 11 mission would result in humankind's first steps on the Moon. Read the feature beginning on page 32. This page: Detail view from Neil Armstrong's position in the lunar module seconds before the touchdown of Apollo 11. Read "Companion to the Stars: The Apollo Guidance Computer," page 40.

COVER: NASA / THIS PAGE: COURTESY OF JOHN KNOLL

CORE

2019



36

THE MOON LANDING @50

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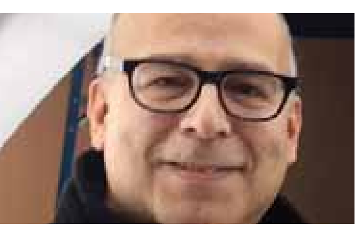

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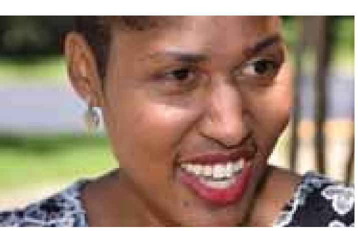
Dag Spicer leads the Museum's collection strategy and supports multiple projects and initiatives across the institution, including those in research, education, fundraising, public programs, and marketing. He is the longest-serving employee at the Museum, having started in 1996, and holds degrees in history, electrical engineering, and the history of science and technology.



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FROM THE CEO

INNOVATE. ADAPT. GROW.

In 2010 a research team led by Riccardo Velasco of the Edmund Mach Foundation, an agrarian institute and wine academy located in Trentino, Italy, sequenced the complete genome of the domesticated apple. It had the highest number of genes of any plant genome to date at 57,000, about 36,000 more genes than humans. Velasco's team identified the *Malus sieversii* as the wild ancestor of the domestic apple, reporting its origins from the hills of Kazakhstan some 3,000 to 4,000 years ago.

The *Malus sieversii*, plagued by a growing number of pests, recent diseases, and a rapidly changing climate, is listed as "vulnerable" on the Red List of Threatened Species by the International Union for Conservation of Nature. As domesticated apples face similar challenges, it becomes imperative for ecologists, farmers, botanists, and the like to learn all they can from the ancient fruit to adapt its modern counterpart. This data will allow new varieties of apple to be developed more quickly than with classical breeding and monoculture farming, resulting in plants that are responsive and resilient against diseases and insects.

This past year, I've been talking about the Computer History Museum (CHM) as a living, growing tree amid a drastically changing museum landscape. Museums around the world are considering how to innovate, adapt, and grow, as they build new mission-related income streams, demonstrate community impact to donors, and create mutually beneficial partnerships. The American Alliance of Museums acknowledged this important moment, dedicating its entire 2019 expo theme to the cause: Dynamic. Relevant. Essential: Sustaining Vibrant Museums.

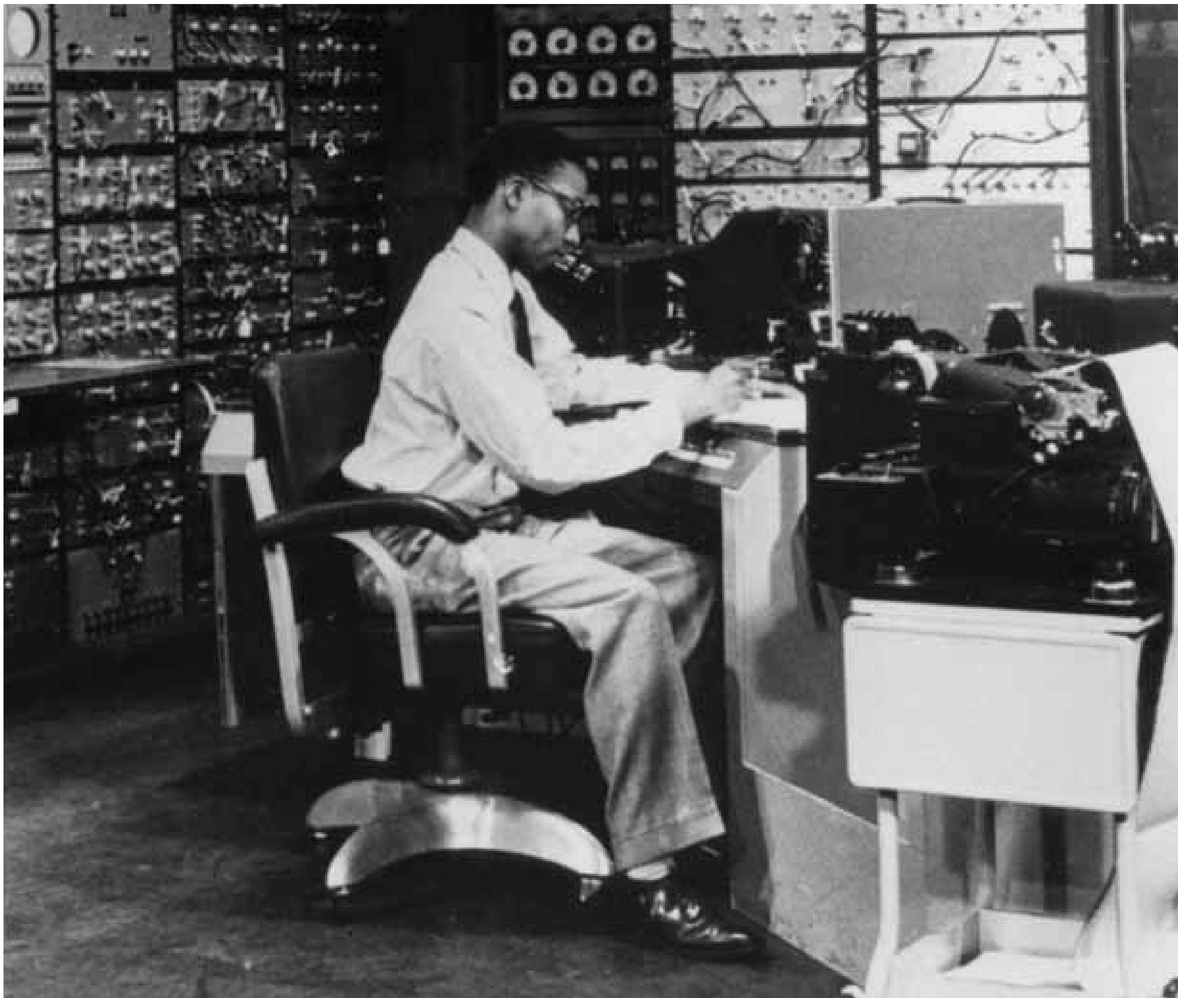
At the forefront of sustaining vibrant museums is technology. Museums from California to Cape Town are turning their attention to technology as a tool that can revitalize their infrastructure to improve visitor experience, reach and expand audiences, and craft business strategies that can help scale their work. This is all part of being a dynamic and relevant museum underpinning what makes museums essential—their position of public trust as stewards of history and storytellers.

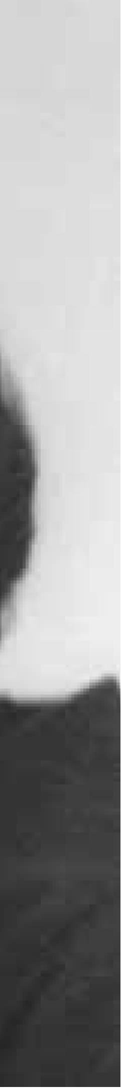
This issue of *Core* reflects a number of stories (featured prominently throughout are excerpts from our oral history collection) that exemplify the ways in which people innovate, adapt, and grow, as well as our own efforts to do the same in our operations. You'll read about a shift in collecting strategy to expand the known history of computing through "outsider narratives"; the journey from idea to startup of well-known entrepreneurs, like Yahoo! founders Jerry Yang and David Filo and Kiva executive chair Julie Hanna; and several extraordinary stories about the history, people, and future of space exploration as we celebrate the 50th anniversary of the Moon landing this July.

We're tremendously grateful for our *Core* readership, and I hope you enjoy reading about and will continue to follow our journey as we innovate, adapt, and grow.

DAN'L LEWIN
PRESIDENT & CHIEF EXECUTIVE OFFICER

MUSEUM UPDATES





To expand the story of computing, CHM is collecting "outsider" narratives—like Tymshare's Ann Hardy, Whirlwind's Joe Thompson, Community Memory's Lee Felsenstein, and entrepreneur and advocate for women in computing Dame Stephanie Shirley.

OPPOSITE PAGE: HARDY: COURTESY OF ANN HARDY; THOMPSON: COMPUTER HISTORY MUSEUM, 102622504 / THIS PAGE: FELSENSTEIN: COMPUTER HISTORY MUSEUM, 102774062

COLLECTION

COLLECTING OUTSIDER NARRATIVES

BY PAULA JABLONER
DIRECTOR OF DIGITAL COLLECTIONS & CENTER FOR CISCO HERITAGE

Contemporary collecting insti-tutions, like CHM, have a responsibility to the public they serve and the narratives they explore. This responsibility demands a critical eye on how and what they collect, and it means asking important questions. How do we collect stories that may have previously been overlooked or otherwise deemed historically insignificant? How is collecting impacted when our understanding of "history-makers" and "computing," in CHM's case, have previously been narrowly defined? How will cultural shifts redefine these terms and affect collection development strategies? These questions do not require a wholesale shift in collecting but consistent thoughtfulness and refinements over time.

There are many current examples on reshaping collecting strategy to include outsider narratives. In perusing the November/December 2018 professional magazine *Archival Outlook*, articles include "Alternative Music and Experimental Collaborations," "Sanctuary at Oberlin: the Archives Bear Witness," "The HistoryMakers: Building African American Cultural Equality," and "ARCHIVES Have the POWER to BOOST Marginalized VOICES [original formatting]."[1] Professionally, diversity in collecting is about our intentions, the stories we want to preserve, and engaging communities around the world as much as amassing historical artifacts.

The lack of diversity in computing is an ongoing topic of conversation both in the media and at CHM. As a cultural institution, how much are we a mirror of the technology world we collect? By expanding our collection development strategies, can we also expand the historical narrative for current and future generations? The Museum's longstanding programs and more recently established centers of expertise aim to expand the understanding of technology through specialized areas of focus. The Software History Center and the Internet History Program both bring a wider view to collecting and explore the evolution and ongoing impact of our connected world. The Exponential Center focuses on capturing the legacy and advancing the future of entrepreneurship and innovation in Silicon Valley and around the world. These initiatives emphasize collecting and stories not just of innovators, visionaries, and disruptors, but of a varied and unexpected set of individuals—"outsiders."

From the Museum's 1970s founding in Boston to its 21st-century presence in Silicon Valley, CHM has followed an additive approach to collecting. The Museum's collecting focus has shifted over these years, taking into account changes in the technology industry and evolving scholarship and research. In the 1970s and 1980s the Museum's founders were concerned about the loss of many first-generation pioneering computers. We focused then on collecting the associated hardware, with a smattering of other historical objects to provide context and guide interpretation, including manuals and photographs. With the move to Silicon Valley in the 1990s, the Museum actively expanded its collecting scope with considerable emphasis on bringing in archival, audio-visual materials, and historical software to create a research collection in support of our own exhibits and interpretation as much as outside researchers. We began an active Oral History Program in 2002, and with a threefold increase in staff since then, we have an excellent opportunity to broaden collecting, allowing us to engage in a proactive and inclusive collecting strategy.

We actively collect the stories of underrepresented individuals, and we have made great strides representing the stories of women in computing. In a 2016 interview for our Software History Center and Internet History Program, programmer and entrepreneur Ann Hardy had more than a few stories to share about her experience as a woman in the early computing industry. In the late 1960s, while working as a programmer and manager at Tymshare, she recalls:

> *So one time I finally got annoyed that I wasn't getting any stock options [at Tymshare] and all the men who were working for me were getting stock options. So GE happened to be advertising for somebody, a programmer, with my experience. And so I sent them my résumé. And I called them up the next week and I talked to the woman in personnel and said, "I sent you my résumé. Can I interview for a job?" And she said, "Well, it is true that your résumé fulfills our requirements better than any others we have received, but we do not hire women in technical positions. And besides that, you have management experience and we can't possibly ask a GE man to ever work for a woman."*[2]

Another program that has exemplified a broadening of both collecting and interpreting outsider narratives is the Museum's Fellow Awards. The Fellow Awards have honored 80 distinguished technology pioneers, naming its first fellow in 1987, Grace Hopper, an icon of software programming. The Fellow Awards involve many museum functions, including collecting, education, research, and media efforts that reflect the seminal work of each Fellow and celebrate their contributions.

In 2018 CHM honored Dame Stephanie Shirley as one of the year's three Fellow Award recipients. In 1962, Shirley founded Freelance Programmers, a UK company that trained and offered women employment in the computing field. By 1975, the company employed 300 programmers—297 of them women. The original telecommuting experiment, the firm encouraged women to work from home and equipped them with resources to learn how to program. Shirley signed all correspondence "Steve Shirley," as early on she realized that men only responded to Steve.

Women in computing are not the only indicator of broadened collecting at CHM. In 1951, African-American Joe Walter Thompson was the first person trained as an operator on MIT's brand new Whirlwind computer. He went on to work as a programmer for RAND, becoming a group manager for the SAGE continental air defense system, designed to respond to Soviet bombers during the Cold War. In his oral history with the Software History Center, Thompson shares a story from his time at RAND, not about computing but about humanity:

> *There's a young man from Texas and he was using derogatory terms for black people. So one day, he was in his office. I went in, closed the door and talked to him about getting his act together. And we became the best of friends…it was a case of what you learn as a child and if no one interrupts and gets you involved in something else, you will continue to do that which you learned. And so to me this was a beautiful experience—not as his director or his supervisor, but as a friend. And so I thought that was neat.* [3]

Thompson also recalls that he did well in school, receiving all As, but that just like his uncle, his ambition was to be a barber. When asked how he got connected with MIT, he says:

> *But they, at MIT, were looking for bright young kids who were not going to college. So, they interviewed kids from all the surrounding high schools. Then I got picked as the first one to do that [to operate Whirlwind]. And so, that's how I got involved. I've never had to look for work since."*[4]

Thompson went on to complete a degree at MIT night school while working full-time.

The Museum also has a strong record of collecting computing and its counterculture. (It doesn't hurt to be located in the San Francisco Bay Area.) For example, the Community Memory Project was a radical idea when computers were seen by the counterculture as tools of government and corporate power. Anyone could post messages using the terminals, which were placed throughout Berkeley and San Francisco and connected by a timeshared mainframe computer. It was Craigslist before Craigslist, run by a dedicated group of volunteer computer nerds. The Museum's collection contains software, terminals, administrative records, promotional material, discussion board printouts, designs, and specifications along with a smattering of other materials focusing on social issues and technology.

The records of Ideographix are a wholly unique collection that explores computing through language and cultural diversity. Founded by Chan Yeh in 1975, Ideographix is known for making the world's first system to automate Chinese typesetting by creating a special keyboard with a capacity to type and print 3,000 characters using specialized software.

The concept of what defines computing has expanded at an unprecedented rate over the last 50 years, to the extent that many believe we have entered into the Fourth Industrial Revolution. Museum collecting requires keeping pace and being at the forefront of thinking about how we collect around continuous change and stories not yet recognized as historically significant. Our centers of expertise and programs, like the Internet History Program, Fellow Awards, and Oral History Program, allow the Museum to expand its collecting scope, providing mechanisms for thinking more holistically and being inclusive in our collecting strategy. We have acquired some great stories and have our eye set on collecting many more. Historians of the future will want to know the "outsider" stories of Ann Hardy, Dame Stephanie Shirley, Joe Thompson, Chan Yeh, and Community Memory.

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1 *Archival Outlook*, Society of American Archivists, November/December 2018

2 Oral history of Ann Hardy, interviewed by David C. Brock, Hansen Hsu, and Marc Weber, July 11, 2016, Computer History Museum, X7849.2017.

3 Oral history of Joseph (Joe) Thompson, interviewed by David C. Brock, February 19, 2019, Computer History Museum, X8499.2018.

4 Thompson/Brock, 2018.

The 8th West Coast Computer Faire crowd, 1984.

JIM C. WARREN/COMPUTER HISTORY MUSEUM, 102640655

JIM C. WARREN PAPERS CHRONICLE THE GOLDEN AGE OF PERSONAL COMPUTING

BY SYDNEY OLSON
REFERENCE & PROCESSING ARCHIVIST

Jim Warren is the founder of the West Coast Computer Faire, a publisher of computing-related periodicals, an engineer, and a political activist. His papers, ranging from 1956 to 2000, document his founding and chairmanship of the fair, his publications and writing career, and his technological consulting projects and research. The collection also includes conference and workshop materials, newsletters from computer clubs and organizations, and over 40 linear feet of software.

In 1977 Warren organized the first West Coast Computer Faire, attracting 180 exhibitors and 12,000 attendees. Our collection details his publications from this period, including *Dr. Dobb's Journal of Computer Calisthenics & Orthodontia* and *Running Lite without Overbyte.*

Another interesting portion of the collection chronicles Warren's political activism related to online access and civil liberties. While he worked on a number of projects in these areas, one of the highlights is his work on California Assembly Bill 1624, which passed into law in 1994 and declared that computerized public legislative records must be made available to the public online and at no cost. The collection holds material related to this project, as well as research files on electronic civil liberties, privacy, online security, and cryptography.

Through the Jim C. Warren Papers, researchers can trace not only Warren's role in the popularization of the personal computer, but also the development of the social and political issues that arose as a result.

CENTERS

FROM IDEA TO STARTUP: THE ENTREPRENEUR'S JOURNEY

BY HEIDI HACKFORD
CONTENT & CURRICULUM DIRECTOR, EXPONENTIAL CENTER

Big corporations can often seem remote and "faceless." But the further back you trace a company's history, the closer you come to the person and the idea that started it all. From the mundane to the aspirational, business enterprises can meet a need, share an invention, or tackle a seemingly insurmountable challenge.

Startups are deeply personal endeavors. At CHM's Exponential Center, when we ask founders about the genesis of the idea that set them on the path to becoming an entrepreneur, to the early days of their companies, they often smile and sound a little wistful—for all the hard work and long hours, the heady hopes and daily terrors, the risks and the rewards. How and why do they take the first step from idea to business, exposing their dreams to public judgment, requiring them to relentlessly exploit their strengths and confront their weaknesses? Let's start at the beginning.

"To be an entrepreneur, you really have to be determined to succeed or die trying."

—WILLIAM H. DRAPER III, PIONEERING VENTURE CAPITALIST[1]

Yahoo! founders David Filo and Jerry Yang in 1999, three years after the company went public.

> **"Great companies are built around great discoveries, great inventions, great new technologies."**
>
> —JOHN HENNESSY, CHAIR, ALPHABET AND FORMER PRESIDENT OF STANFORD UNIVERSITY

YAHOO! FOUNDERS COLLECTION, COMPUTER HISTORY MUSEUM, 102789051

That "Ah-ha!" Moment

It's night. In Boston. In February. And the dog is out of food. For Leah Busque, this scenario resulted in an idea that eventually became TaskRabbit, a pioneer in the sharing economy before that business model had a name. On that cold, snowy night, she imagined how great it would be to connect with someone in her community—maybe a neighbor already running errands who would be willing to pick up some dog food for a fee. Sitting down at her computer, she coded the germ of a new enterprise. Later, she left her day job and transformed her idea into a company that eventually earned the backing of venture capitalists, engaged 60,000 people, and spread to 44 cities in the US and Europe before being bought by IKEA in 2017.[2]

For Jerry Yang and David Filo, there was a natural progression from their original idea to what would become Yahoo. In their joint oral history, Jerry Yang says:

> *…we certainly never sat down one day and said, "Let's go create this thing and have a long-term plan for it."…we were just finding ourselves with more free time and spending—and being intrigued by this new web thing more and more…So, anyway, that led us to create some very basic tools just for our own use of basically categorizing and saving the different sites that we were visiting.*[3]

These basic tools became "Jerry's Guide to the World Wide Web," a directory of early websites with links that Jerry and David offered to the public for free. With a name change to Yahoo!, the directory was the fourth most visited website when the company went public in 1996 and took the lead from 2004 to 2007.[4]

Developing and sharing a tool to solve a personal problem, need, or desire, as Leah Busque and the Yahoo! founders did, is common among entrepreneurs, even for global brands. Silicon Valley angel investor Ron Conway says:

Top: Apple's Steve Wozniak and Steve Jobs in 1976, the year the company was founded. Bottom: Mike Markkula's memo calls out the company's success.

APPLE BULLETIN

January 13, 1983

Apple's sales in December of 1982 reached an all-time monthly high of nearly $90 million. This set a record for our industry and made Apple the first personal computer company to reach a sales rate of $1 billion on an annualized (December x 12) basis.

A further source of pride for everyone at Apple is the distinction given us in Forbes' 35th Annual Report on American Industry, published January 3rd.

Our five-year corporate performance was ranked "indisputably number one" among the more than 1,000 companies listed on three key yardsticks: return on equity, return on total capital, and growth in sales. Fiscal 1982 was Apple's first year in this report (companies must exceed $400 million in sales), and Forbes notes that our debut was "spectacular indeed."

The measures on which we scored first are those by which Forbes judges giant corporations. Our ranking shows again that we have gone from the biggest of the small to the smallest of the big guys in this high stakes arena.

Everyone deserves congratulations for a job well done.

Now is the time for us to re-dedicate ourselves to meet the more difficult challenges ahead.

A.C. Markkula, Jr.
President and Chief Executive Officer

	Profitability								Growth			
	Return on equity				Return on total capital				Sales		Earnings per share	
Company	5-year rank	5-year average	latest 12 months	debt/ equity ratio	5-year rank	5-year average	latest 12 months	net profit margin	5-year rank	5-year average	5-year rank	5-year average
Apple Computer	1	118.6%†	43.0%	0.0	1	130.9%†	33.3%	10.5%	1	154.3%††	1	127.2%††
Wang Laboratories	2	32.4	21.4	0.6	4	20.9	15.3	9.3	2	49.8	2	50.5
Storage Technology	3	29.3	17.8	0.5	5	20.1	13.0	8.1	3	45.7	3	37.6
IBM	4	22.4	20.8	0.2	2	20.9	18.4	11.8	11	12.6	11	10.0
Hewlett-Packard	5	19.8	19.5	0.0	6	19.1	18.7	9.0	7	24.6	7	22.8

Reprinted from the Forbes article, page 124.

WOZNIAK AND JOBS: JOE MELENA/COMPUTER HISTORY MUSEUM, 102665181; APPLE BULLETIN: MIKE MARKKULA COLLECTION OF EARLY APPLE COMPUTER MATERIAL, COMPUTER HISTORY MUSEUM, X4554.2008.

If you look at Steve Chen and Chad Hurley at YouTube, they took videos at a dinner party, wanted to share them with their friends, and there was no easy way to do that on the web. So they said, 'Let's go write some software just so we can share our videos among our friends.' And Kaboom!, you know, YouTube happens.[5]

But companies don't just "happen." How exactly does a person take the step from a promising idea to founding a business?

Meeting Obligations

Focused on getting their idea to work, founders are not usually considering all the implications of what might happen when it does. For some, like Coursera's Daphne Koller, before they know it, users or customers are counting on them to deliver.

When she was a computer science professor at Stanford University, Koller felt she was not providing the best educational experience possible by lecturing to large classes of students. So, she and her colleague Andrew Ng created an engaging and instructive experience online, reserving class time for discussion. As the online experience developed, Koller and Ng decided to make the course available outside Stanford to those who might otherwise never have the opportunity to learn at a world-class university. When 100,000 people from all over the world enrolled in that first online class, she and Ng realized the impact their model could have and felt obligated to move forward and create the online learning platform that became Coursera. In Koller's words, she "couldn't not do it."[6] Yahoo's David Filo echoes those feelings:

We had created this thing now that people were using and kind of depending on in some way…And we felt obligated to keep it going.[7]

The best companies infuse their culture with that sense of commitment to customers as they grow, but it can also provide something else that encourages founders to move forward: proof there is a market for their product. Steve Wozniak describes the moment when that happened for Apple:

I was a hero at the [Homebrew Computer] club. I demonstrated my computer every two weeks. I had passed out my designs. I'd helped other people build theirs. So I took Steve [Jobs] to the club to show him what it was about. And he stood back and watched. About 30 people would crowd around me as I'm doing my demo, typing things and they're asking questions and I'm explaining what it's gonna do next. And after that, Steve said, "We should start a company."[8]

"Any problem worth solving is going to take time…as long as you can hunker down and live to see another day and persist—and you've got a good idea—you've got a pretty good shot at succeeding."

—JIM POLESE, CHAIRMAN, CROWDSMART AND COFOUNDER, MARIMBA OF STANFORD UNIVERSITY

Steve Jobs made the leap from Wozniak's idea—a personal computer for himself—to the vision for a company. And when Jobs famously sold his VW bus and Woz his beloved HP calculator to raise the money for their startup, the two Steves committed to becoming entrepreneurs.

Partners and Teams

No matter how smart, skilled, and committed they are, every founder story includes a larger cast of team members. Serial entrepreneur Diane Greene, cofounder of VMware and former CEO of Google Cloud, says she's always had cofounders because it's more fun to start a company with someone else, and she believes in the importance of building a great team, "brick by brick." She even used friendly VMware all-hands meetings to combat her fear of public speaking; as the company added employees she gradually became comfortable in front of larger and larger audiences.[9] Finding partners who complement a founder's skillset and building an effective team is one of the most important tasks for any startup and potential funders know it.

When legendary venture capitalist Don Valentine was introduced to Jobs and Wozniak and invited to fund their new company, he instead recommended that Mike Markkula, an experienced marketing executive who had retired early from Intel, mentor them. He invested in the company, secured funds from venture capitalists, recruited leadership, and served as chair of the board, steering Apple to become a Fortune 500 company in five years. Woz describes Markkula's key role from his perspective:

Steve and I were in our young 20s. We had no business experience at all.… And, so Mike Markkula who funded us was the adult. And he started teaching principles of marketing to Steve who liked that 'cause Steve didn't know the engineering. But he wanted to have a major business role in the company. And Mike Markkula said that Steve Jobs' role would be to learn all the departments of a company.…"To have a technology company," Mike Markkula said, "These are the roles that you hire. And here's what their responsibilities are. And here's how it works." So Mike was the adult that really set up the company. And he made us be professional. "You must wear a suit to this introduction of the Apple II." That sort of thinking.[10]

“You are going to work hard and fail. Expect to put in 10–15 years. Ask for help and help others. That’s the magic of Silicon Valley.”
—TONY FADELL, APPLE IPOD INVENTOR AND COFOUNDER, NEST

Top: Executive Director of the Exponential Center Marguerite Gong Hancock interviews Kiva’s Julie Hanna. Bottom: Cofouder and Chief Operating Officer of Cloudflare Michelle Zatlyn shares her advice for entrepreneurs.

Perhaps Apple, the first trillion-dollar company, would not exist without Markkula’s skilled guidance in its crucial early years. But, it’s important to note that he was able to draw on the resources available in Silicon Valley.

It Takes a Valley

In addition to strong, cohesive teams, startups often benefit from their business ecosystem—the other companies, legal and venture capital and accounting firms, universities and research centers, customers, suppliers, and a skilled workforce in a particular region. Ecosystems that are conducive to entrepreneurship provide founders with help from people who are experienced in launching, funding, managing, advising, and working in startups. Cloudflare’s Michelle Zatlyn and her cofounders moved from Boston to start their internet security company because they needed people with specific experience in internet scaling as well as large amounts of venture capital, both of which were only available in Silicon Valley.[11] But perhaps most importantly, entrepreneurial ecosystems can provide a history and culture that understands what it takes to build a company from scratch, how hard it is, and that forgives mistakes.

Although it may be the most well-known, Silicon Valley is not the only region with an ecosystem that supports the development of new enterprises. Julie Hanna, executive chair of Kiva, a crowdfunding site for small-scale international startups, and was the presidential ambassador for global entrepreneurship in the Obama administration, found the startup mindset everywhere she went as she traveled the world.[12] Perhaps the compulsion to fix things, start things, share something new, is a universal human trait. Changing the world starts with one person and one idea and a little help from the rest of us.

The lobby exhibit includes a 27-foot wall display and an interactive "talk back" board, where visitors can post and share their inspiring one word.

[1] Pull quotes in this article are drawn from comments made by participants during live programs produced by the Exponential Center.

[2] Leah Busque related this story in a CHM Live event, "Fire and Fuel: Founders and Funders," on May 16, 2018.

[3] Oral history of David Filo and Jerry Yang, interviewed by Marguerite Gong Hancock and Marc Weber, February 27, 2018, Computer History Museum, X8518.2018 (forthcoming).

[4] Philip Bump, "From Lycos to Ask Jeeves to Facebook: Tracking the 20 Most Popular Web Sites Every Year Since 1996," the *Washington Post*, December 15, 2014, https://www.washingtonpost.com/news/the-intersect/wp/2014/12/15/from-lycos-to-ask-jeeves-to-facebook-tracking-the-20-most-popular-web-sites-every-year-since-1996/?utm_term=.74221114d994.

[5] Ron Conway interview for *Silicon Valley: The Untold Story*, November 20, 2013, courtesy of Kikim Media.

[6] Daphne Koller related this story in a CHM Live event, "Wonder Women: Entrepreneurship, Education, and New Frontiers," on November 7, 2017.

[7] Filo and Yang/Gong Hancock and Weber, 2018 (forthcoming).

[8] Steve Wozniak interview for *Silicon Valley: The Untold Story*, December 2, 2016, courtesy of Kikim Media.

[9] Diane Greene participated in a CHM Live event, "Building Ships, Companies, and the Cloud," on July 18, 2017.

[10] Wozniak/*Silicon Valley,* 2016.

[11] Michelle Zatlyn participated in a CHM Live event, "Pioneers of the Possible: Women Entrepreneurs on Innovation and Impact," on September 22, 2016.

[12] Julie Hanna participated in a CHM Live event, "The Next Billion," on November 16, 2016.

"All of the accomplishments that we attribute to any individual Silicon Valley entrepreneur hero if you dig the tiniest bit beneath the surface, you discover that there's an entire team who made that happen."

—LESLIE BERLIN, PROJECT HISTORIAN FOR THE SILICON VALLEY ARCHIVES AT STANFORD UNIVERSITY

SILICON VALLEY LEADERS SHARE ADVICE IN "ONE WORD" EDUCATIONAL INITIATIVE

BY HEIDI HACKFORD
CONTENT & CURRICULUM DIRECTOR, EXPONENTIAL CENTER

Courage, Creativity, Bold, Be Humble, Grit, Kindness... These are just a few of the words of advice offered by Silicon Valley leaders such as Apple's Steve Wozniak, Floodgate's Ann Miura-Ko, and Alphabet's John Hennessy to aspiring entrepreneurs. They are featured in the One Word educational initiative spearheaded by the CHM Exponential Center. The multiformat project aims to inspire and motivate people to think about what it takes to start and build a company. The initiative includes a 27-foot tall exhibit in the CHM lobby highlighting successful Silicon Valley founders and builders with a touchscreen to explore their stories and those of additional leaders. A "selfie wall" allows visitors to select, post, and share their own word of inspiration. There is also a companion book for sale in the Museum Store and workshops and live programs taking place throughout 2019. Educational curriculum and digital content amplify the message that by building strong teams with complementary skills—and learning from voices of experience—anyone can become an entrepreneur.

One Word is made possible by the generous support of the Patrick J. McGovern Foundation.

CENTERS

THE DYNABOOK WAS NOT AN IPAD

BY HANSEN HSU
CURATOR, SOFTWARE HISTORY CENTER

Replica of Alan Kay's original 1968 Dynabook mockup, recreated by Kay for CHM, on display in *Revolution*'s Mobile Computing Gallery.

Alan Kay's Dynabook is usually credited as a visionary prototype for the mobile computers we use today: laptops, smartphones, and tablets. As imagined in his seminal 1972 paper, "A Personal Computer for Children of All Ages,"[1] the Dynabook would have been very close to a modern iPad:

> *The size should be no larger than a notebook; weight less than 4 lbs.; the visual display should be able to present at least 4,000 printing quality characters with contrast ratios approaching that of a book; dynamic graphics of reasonable quality should be possible; there should be removable local file storage of at least one million characters (about 500 ordinary book pages) traded off against several hours of audio (voice/music) files.*[2]

It would have a flat-panel LCD display[3] and a physical keyboard that Kay envisioned could be replaced by a virtual one:

> *Suppose the display panel covers the full extent of the notebook surface. Any keyboard arrangement one might wish can then be displayed anywhere on the surface.*[4]

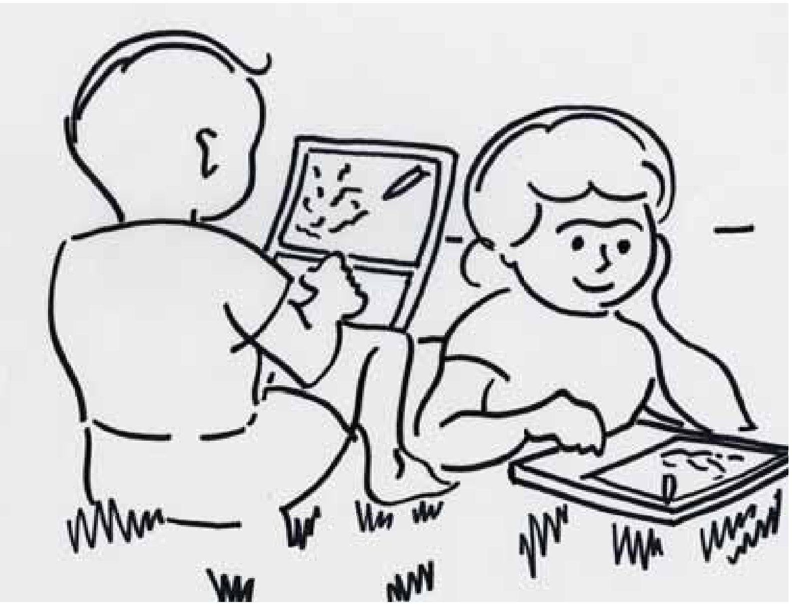
The Dynabook would have multiple fonts and a simple object-oriented programming language. It would have an always-on wireless connection to the net:

> *A combination of this 'carry anywhere' device and a global information utility such as the ARPA network or two-way cable TV, will bring the libraries and schools (not to mention stores and billboards) of the world to the home."*[5]

It would be affordable at $500, costing about the same as a TV, and intuitive for all users, especially children. Kay's vision of personal and mobile computing reflected much of the industry's research and development from the 1970s through the 2000s.[6] Beginning with Xerox's Palo Alto Research Center (PARC), the Alto computer, which Kay called the "interim Dynabook," became the paradigm for all modern personal computers from the Apple Macintosh onward. Kay's concept of mobile computing has inspired a litany of computers with notebook and handheld form factors, from the Apple PowerBook and PDAs like the Newton and the PalmPilot to the OLPC (One Laptop Per Child) and today's tablets. His former colleague at PARC, Chuck Thacker, a principal designer of the Alto, became a key contributor to this legacy, helping to develop Microsoft's Tablet PC effort in the late 1990s and 2000s. Despite this legacy, Kay has insisted that:

> *The most misunderstood thing about the Dynabook is this idea that it's some kind of box. It isn't a box. It isn't a piece of hardware…"*[7]

What is the Dynabook, then, if it isn't a tablet computer? Kay says that it's a service: "It's a DynaBook [sic] if it gives you your information services wherever you are on Earth."[8] Throughout "A Personal Computer for Children of All Ages," Kay refers to the Dynabook as not just a tool, but also a "medium" that is active and engaging like a book or piano, rather than passive like television. Kay imagines an elaborate scenario in which two children are playing a space simulation game (similar to *SpaceWar*) together on their Dynabooks. One decides to modify the game to incorporate a gravity source, looking up information on the network to help her do so. She programs the modifications and then proceeds to defeat her companion. Kay defined the term "personal computer" to be a Dynabook, as "both a medium for containing and expressing arbitrary symbolic notions, and also a collection of useful tools for manipulating these structures, with ways to add new tools to the repertoire."[9]



Children using proposed Dynabooks, based on a drawing by Alan Kay appearing in "A Personal Computer for Children of All Ages," 1972.

What is implicit in 1972, Kay makes explicit in later writings that his idea of computers as media was shaped by Marshall McLuhan:

> *I read McLuhan's* Understanding Media *[1964]*[10] *and understood that… anyone who wishes to receive a message embedded in a medium must first have internalized the medium… When he said "the medium is the message" he meant that you have to* become *[emphasis in original] the medium if you use it. That's pretty scary. It means… that it is in the nature of tools and man that learning to use tools reshapes us… McLuhan's claim [about the transformative nature of the printing press]…is that the press didn't do it just by making books more available, it did it by changing the thought patterns of those who learned to read.*[11]

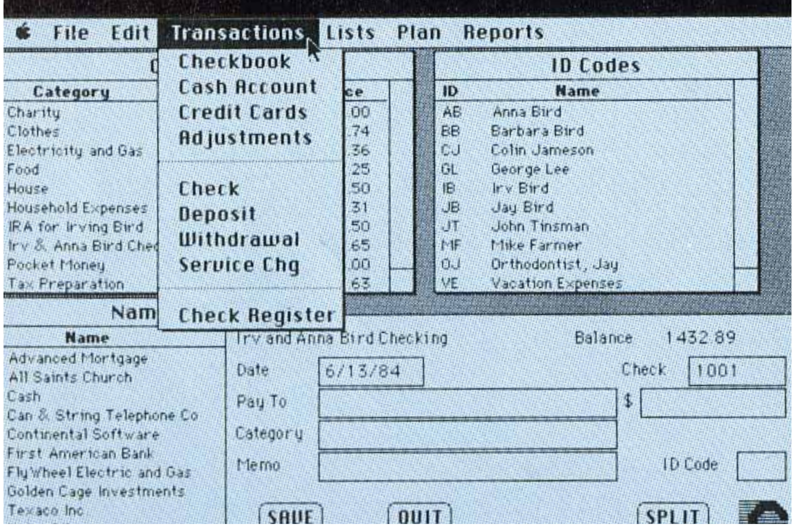
This was a shocking and transformative revelation to Kay:

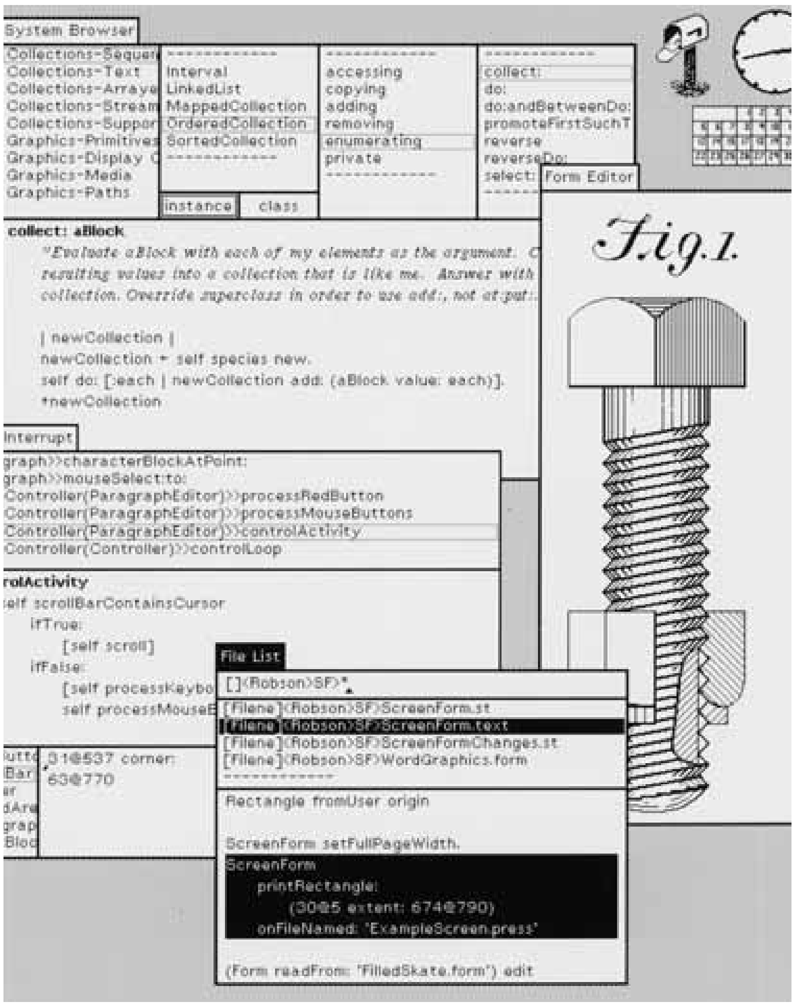
> *The computer is a medium! I had always thought of it as a tool, perhaps a vehicle—a much weaker conception. What McLuhan was saying is that if the personal computer is a truly new medium then the very use of it would actually change the thought patterns of an entire civilization… it promised to surpass the book…by going beyond static representations to dynamic simulation… I named the notebook-sized computer idea the Dynabook to capture McLuhan's metaphor in the silicon to come.*[12]

Moreover, Kay asserts that the Dynabook is not just a medium, but a "metamedium." This is because of the universal quality of computers to simulate other machines and systems:

> *The ability to simulate the details of any descriptive model means that the computer, viewed as a medium itself, can be* all other media *[emphasis in original]…"*[13]

© ALAN KAY/COURTESY OF ALAN KAY





The graphical user interface of the Macintosh was inspired by that of Smalltalk at Xerox PARC.
Top: Screenshot of Macintosh, 1984. Bottom: Smalltalk-80 interface, 1980.

This conception of computers as media had a number of corollaries. First, children must have early access to computers:

> *If the computer is only a vehicle, perhaps you can wait until high school to give 'driver's ed' on it—but if it's a medium, then it must be extended all the way into the world of the child.*[14]

It becomes imperative that children gain literacy in the medium as early as possible.

Second, this literacy means being able to not just passively consume, but to actively create and modify, as in the scenario Kay described in 1972 with the two children on their Dynabooks:

> *This new "metamedium" is* ACTIVE *[emphasis in original]—it can respond to queries and experiments—so that the messages may involve the learning in a two-way conversation."*[15]

He continues:

> *"The ability to "write" in a medium means you can generate [emphasis in original] materials and tools for others. You must have both [reading and writing] to be literate…In computer writing, the tools you generate are processes; they simulate and decide.*[16]

This means that "end users needed to be able to program before the computer could become truly theirs…"[17]

Kay and his Learning Research Group (LRG) at PARC coupled McLuhan's philosophy with the ideas of child psychologists Jean Piaget and Jerome Bruner with aspects of Seymour Papert's LOGO language to develop the object-oriented Smalltalk language for children. Fitting in with Kay's initial Dynabook vision, Smalltalk enabled children to dynamically simulate real-world systems on their computers through graphics, animations, and sound. Kay hired Adele Goldberg into LRG to set up labs at local Palo Alto schools where children could play with Smalltalk on Alto computers. Junior high school kids learned to write paint programs, animation programs, and compose musical scores.[18]

Smalltalk further exemplified Kay's thinking as both a programming language and a graphical user environment that could be explored and modified by the user. This was exemplified in the famous demos of Smalltalk that PARC gave to Steve Jobs and Apple in 1979. Dan Ingalls, the lead developer of Smalltalk, was running the demonstration when Jobs asked if the scrolling behavior could be changed from a jerky one-line-at-a-time to a smooth one-pixel-at-a-time. While Jobs was away at lunch, Ingalls figured out how to make this change in one line of code. When Jobs returned, Ingalls made the change live, recompiled the code on the fly and the new behavior was instantly available.[19] Smalltalk's windows and menus convinced Jobs that Apple needed to make computers with graphical user interfaces, leading to 1984's Macintosh. However, Jobs did not believe in Kay's philosophy that the user should be able to change anything in the system. Rather, Apple's philosophy in the Mac would be to simply the interface by giving users fewer choices and limited customization options. The same philosophy guides the design of the iPhone and iPad today.

What then, is a Dynabook? For Kay, it is no less than a "personal dynamic medium" for access to the world's knowledge and information repositories. To be "personal," it must be intimate, portable, mobile, accessible, affordable—dictating the notebook-size design. It must be a friendly and accessible learning aid for children. As a "dynamic medium," it must be networked, so that unlike a static book, endless content is available: "'Books' can now be 'instantiated' instead of bought or checked out."[20] All the world's libraries and information services must be available from anywhere on the planet.

So far, what we're describing sounds just like an iPad. But for Kay, the iPad does not go far enough. More than just providing passive consumption of content, the "Dyna" in Dynabook means that the user must be able to engage actively with the media. For children, this means enabling learning through the creation of realistic working simulations of the world inside the computer.[21] It means stimulating the creation of new ideas, art, and music. And it means being able to explore the system itself, learn about it, and change things to one's own liking, something which today's locked-down "walled gardens" do not allow. In many ways, today's tablet computers fulfill remarkably well Kay's almost 50-year-old dream. But we are not quite there yet. ○

Alan Kay discusses his 1968 Dynabook model in a lecture and panel discussion at CHM in honor of the 40th anniversary of the Dynabook in 2008.

[1] Alan Kay, "A Personal Computer for Children of All Ages," in *Proceedings of the ACM Annual Conference—Volume 1, ACM 1972* (New York, NY, USA: ACM, 1972), https://doi.org/10.1145/800193.1971922.

[2] Kay, 6.

[3] Inspired by a trip to the University of Illinois where he saw an early flat-panel plasma display, Kay imagined what might happen if he attached such a flatscreen to the desktop computer he was working on in graduate school, the FLEX, and mocked up a prototype in cardboard, the first vision of the Dynabook, in 1968. A recreation of the cardboard prototype by Alan Kay is on exhibit at the Computer History Museum and is part of the Museum's collection, catalog no. 102716364, http://www.computerhistory.org/collections/catalog/102716364.

[4] Kay, "A Personal Computer for Children of All Ages," 8.

[5] Kay, 6.

[6] Oral history of Charles (Chuck) Thacker, interviewed by Al Kossow, August 29, 2007, Computer History Museum, http://www.computerhistory.org/collections/catalog/102658126; John Markoff, "Microsoft Brings In Top Talent To Pursue Old Goal: The Tablet," *New York Times*, August 30, 1999, sec. Business Day, https://www.nytimes.com/1999/08/30/business/microsoft-brings-in-top-talent-to-pursue-old-goal-the-tablet.html; "The Xerox Alto: A Personal Retrospective," *The Computer Museum History Center Lecture Series* (Computer History Museum, 2001), https://youtu.be/2H2BPrgxedY; Microsoft, "Honoring Charles P. Thacker, a Visionary Computer Scientist Who Changed the World," *Microsoft Research* (blog), June 20, 2017, https://www.microsoft.com/en-us/research/blog/charles-p-thacker-visionary-computer-scientist/.

[7] Alan Kay, "The DynaBook: Past, Present, and Future" (January 9, 1986), https://youtu.be/GMDphyKrAE8.

[8] Kay.

[9] Kay, "A Personal Computer for Children of All Ages," 3.

[10] Marshall McLuhan, *Understanding Media: The Extensions of Man*, 1st ed. (New York: McGraw-Hill, 1964).

[11] Alan Kay, "User Interface: A Personal View," in *The Art of Human-Computer Interface Design*, ed. Brenda Laurel and Joy Mountford (Addison-Wesley, 1990), 124.

[12] Kay, 124–25.

[13] Alan Kay and Adele Goldberg, "Personal Dynamic Media," *Computer* 10, no. 3 (March 1977): 31, https://doi.org/10.1109/C-M.1977.217672.

[14] Kay, "User Interface," 125.

[15] Kay and Goldberg, "Personal Dynamic Media," 31.

[16] Kay, "User Interface," 125.

[17] Kay, 125.

[18] Kay and Goldberg, "Personal Dynamic Media"; Marian Goldeen, "Learning About Smalltalk," Creative Computing, October 1975. The Goldeen sisters later became software engineers who today work at Apple, Inc. Personal communication with Marian Goldeen.

[19] Michael A. Hiltzik, *Dealers of Lightning: Xerox PARC and the Dawn of the Computer Age*, 1st ed. (New York: HarperBusiness, 1999), 341; Oral history of Dan Ingalls, Computer History Museum, forthcoming; "Dan Ingalls Demonstrates SmallTalk," Alto System Project, Computer History Museum, March 12, 2019, https://youtu.be/uknEhXyZgsg.

[20] Kay, "A Personal Computer for Children of All Ages," 6.

[21] Kay, "User Interface," 128–29.

UNIX: THE CODE BEHIND YOUR WORLD

BY DAVID C. BROCK

DIRECTOR & CURATOR, SOFTWARE HISTORY CENTER

What runs the servers that hold our online world, be it the web or the cloud? The answer is the operating system UNIX and her many children: Linux, Android, BSD, significant portions of Apple's iOS and macOS, and more. 2019 marks the 50th anniversary of UNIX. In the summer of 1969, computer scientists at the Bell Telephone Laboratories—most centrally Dennis Ritchie and Ken Thompson—began constructing a new operating system, using an almost forgotten DEC PDP-7 computer. As Ritchie would later explain:

> What we wanted to preserve was not just a good environment to do programming, but a system around which a fellowship could form. We knew from experience that the essence of communal computing [...] is not just to type programs into a terminal instead of a keypunch, but to encourage close communication."[1]

Thompson was the force for developing this system, eventually called UNIX, while Ritchie was key in creating a new programming language for it, called C. Like UNIX, C has been tremendously influential. C and languages inspired by it (C++, C#, Java) are among the most popular programming languages today. The Software History Center is actively collecting around this essential legacy. We recently brought Dennis Ritchie's personal and professional papers into the Museum's permanent collection. We have also received a trove of materials from Kirk McKusick on the evolution of the Berkeley Standard Distribution (BSD) UNIX—central to the development of UNIX itself and also to the free and open source software movement.[2] ○

[1] Dennis M. Ritchie, "The Evolution of the Unix Time-sharing System," October 1984 (original), https://www.bell-labs.com/usr/dmr/www/hist.html.

[2] See Marshall Kirk McKusick, "Twenty Years of Berkeley Unix: From AT&T to Freely Redistributable," *Open Sources: Voices from the Open Source Revolution* (O'Reilly, 1999), https://www.oreilly.com/openbook/opensources/book/kirkmck.html.

LEARNING LAB

By embracing learning in everything we do, CHM is redefining what a museum can and should be in the 21st century, how it can engage people 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.

The CHM Learning Lab, opened in spring 2019, is the newest effort in pursuit of these goals. Designed to encourage multiple modes of learning, the Learning Lab contains hands-on activities, thought-provoking exhibits, and space for programs and live events, all meant to make the history and impact of technology accessible and relevant for visitors of all ages, backgrounds, and interests.

The Learning Lab is also a place where the Museum can learn. Its contents will change over time as we try out new exhibits, seek visitors' feedback about new activities and curriculum, and participate in cutting-edge research, scholarship, and programming at the intersection of technology and learning.

Enjoy this behind-the-scenes tour of the CHM Learning Lab with feature articles by Karin Forssell, PhD, program director and lecturer at Stanford University's Graduate School of Education, and Joerg Student, executive design director at IDEO.

Design conception: IDEO & CHM
Project architect: Mark Horton / Architecture
Exhibit design: Van Sickle & Rolleri

THE HUB

Look around. See what's here. You'll always find something to explore on your own or share with others.

The Hub contains discovery tables where visitors can explore historical artifacts, an interactive wall featuring profiles of inspiring tech innovators from around the world, insights about CHM collections from our teen interns, and opportunities for people to share their own insights. The Hub is the first area visitors encounter upon entering the Learning Lab and it is open as a drop-in space for individuals, families, and small groups whenever the Museum is open.

THE LAB INSIDE

A place for exploration and discovery, available to all when the doors are open. When closed, observe the special projects going on inside.

The Lab Inside is a changing space for investigation of all kinds. Most times, it will be open to the public to participate in entertaining and challenging activities: deconstruct a computer, solve a coded puzzle, or help us experiment with new exhibit techniques. At other times, it will be closed to allow concentrated work by scholars, educators, and Museum staff and partners, giving visitors an insiders' peek into the teaching and learning that help fuel our understanding of technology and its impact.

THE IMAGINARIUM

Discover the creative side of technology and imagine what might be possible.

The Imaginarium is a showcase for noteworthy and creative innovations that use technology in new, unusual, and unexpected ways. Here, visitors will find thought-provoking exhibits of art and music, cutting-edge demonstrations, prototypes of technologies in development, or experimental installations.

HARLAN E. ANDERSON ARENA

A space for classes, programs, and special events. When the door is open, all are welcome to enjoy hands-on activities or just relax and recharge.

The Harlan E. Anderson Arena is the primary space for organized programs and events. Amphitheater-style seating serves as a gathering point at the start or end of a workshop, seating for event attendees, or a presentation stage; whiteboard walls encourage fast prototyping and collaborative learning. The arena is outfitted with technologies that allow remote participation, live streaming, audio- and videoconferencing, and filming and recording of all of these. When not occupied with scheduled programs, the arena is a place for drop-in visitors to relax, recharge, and participate in hands-on activities. ○

Harlan Anderson (1929–2019) cofounded Digital Equipment Corporation (DEC) in 1957. DEC developed the minicomputer, a small, inexpensive system for controlling lab instruments or doing basic office work. It was so successful that at one point, DEC was the second largest computer company in the world.

The Harlan E. Anderson Foundation's support of CHM comes from Anderson's lifelong commitment to ensuring that everyone has access to quality educational programs. Anderson believed that his own access to education dramatically changed his life and that education has the transformative power to improve the human condition for everyone.

CHM's Learning Lab is an innovative new space designed for many learning activities such as observation, building, contemplation, and discussion.

MEGAN V. WINSLOW/LOS ALTOS TOWN CRIER

A SPECIAL PLACE FOR LEARNING ABOUT LEARNING

KARIN FORSSELL
DIRECTOR, LEARNING, DESIGN & TECHNOLOGY PROGRAM
STANFORD GRADUATE SCHOOL OF EDUCATION

Has a physical place ever impacted your learning? I'm sure it has. Whether it was an inspirational piece of art in a hallway, a cozy chair for contemplation, a practice room, or a meeting space, each in its way provided support for activities that helped change what you could say or do.

When you look around CHM, do you see how the spaces help you learn? Certain items are close to others, to spark connections. Exhibits are curated to suggest relationships between objects. Distractions are minimized. Lighting, sound, colors, and touch align to allow you to focus on the objects and the ideas they represent. And a variety of resources and materials are available if needed as you meander through the galleries.

As a learning scientist, I'm interested in designing more effective learning experiences. I find museums to be fascinating places for understanding how people learn. We can see learning happening in a variety of ways. In museums, we can start to understand thought processes by observing the choices that visitors make as they wander.[1] They talk with each other as they contemplate the exhibits[2] and gesture as they refer to artifacts.[3] They refer to a range of information on an as-needed basis.[4]

With so much to observe, it's useful to have a way to organize our thinking. Museum educator Lynda Kelly suggested a "6P learning model" to wrangle the complexity of learning settings into a manageable form. The individual persons, their purposes, the people they're working with, through what processes, and with what products in mind all interact with the places.[5] This framework prompts a variety of intriguing questions.

Person and Purpose: Who are these learners, and why are they here? We all bring our personal interests, our existing knowledge, and our unique perspectives with us to any learning experience. They impact what we notice, seek out, or take with us from a learning setting. From young children encountering artifacts for the first time, to expert docents, there are a range of people learning at museums.

We also have varying reasons for going somewhere to learn. Professor John Falk, an expert on so-called "free-choice learning settings" such as museums, libraries, zoos, and aquariums, has shown that people have a complex set of identities and motivations that are influenced by their social and physical contexts. In museums we are sometimes explorers, sometimes experience seekers, sometimes pilgrims.[6] Designing for this wide range of learners means intentionally creating different ways to engage with the exhibits and themes.

Product: Learn what? In free-choice learning spaces, learners choose to engage in these learning activities on their own time, around a particular topic or skill. They do so without certificates or degrees or grades. They come together with goals such as to increase their understanding and to foster a love of learning.

Very often, those learning goals are a moving target. As learners grow and develop, their understanding of topics evolves and so do the activities that will support their learning journey. A space that is designed for learning has to take into account what people already know, what they will learn, and how they're going to get from the one to the other.

Process: How are they learning? Walk around a school or university campus, a museum or a zoo, and you will find many places for specific interactions that help people learn. You will pass rooms where resources are collected, prompting dialogs around new ideas. You will observe spaces where amateurs try out new skills and get feedback on their performance. You will find quiet corners where neophytes think deep thoughts and messy spaces where learners build and create.

Creating those learning interactions requires a deep understanding of the task at hand. Designers of learning spaces ask not only "What resources will people need?" but also "How can we accommodate learner differences?" "How will learners know if they're on track?" and "How will they recover from mistakes?"

People: Learn with whom? As you explore learning spaces, you will see a wide range of constellations of people. Some will be facing the front of the room, watching demonstrations and listening to explanations. Some will be intently contemplating an informational poster or an exemplary piece of work. Some will be huddled in pairs, deeply engrossed in solving problems. Sometimes small or large groups will be facing each other, tossing ideas and questions back-and-forth.

In museums, visitors come alone, in pairs, in families, on school field trips, with community groups, or with employee teams. Effective designers consider how each configuration can be leveraged for powerful experiences.

Place: What's special about this place? Any built environment is an evolving combination of a site (land), structure (building), skin (exterior), services (plumbing, electrical), spaces (rooms), and stuff (furniture).[7] Some aspects are easier to change than others. The opportunities for learning will vary depending on the unique combination of features of a given place.

CHM offers curated learning experiences for visitors of all ages and backgrounds. Here a family examines the Michigan Micro Mote, the "world's smallest computer," and middle-school students enjoy CHM's Design_Code_Build workshop.

In the new Learning Lab, you will see a space designed to accommodate different types of interactions and learning outcomes for people of varying ages, backgrounds, interests, and preferences. The Learning Lab is modular and flexible, allowing many types of programs, from workshops and speaker events, to school field trips, interactive exhibits, and hands-on activities. In it, CHM will host K–12 students and families, business leaders and policymakers, all engaged in meaningful explorations of learning.

But that's not all. The Learning Lab will also be a place to practice the important work of learning about learning spaces themselves. It has been intentionally created to allow experimentation with a wide variety of activities and configurations. In this space, museum educators can collaborate around questions of how to help spark ideas, make connections, and foster a love of learning.

And that, I think, makes it a very special place.

[1] Sue Allen, "Designs for Learning: Studying Science Museum Exhibits That Do More Than Entertain," *Science Education*, 88, no. S1 (2004): S17-S33.

[2] Minda Borun, Margaret Chambers, and Ann Cleghorn, "Families Are Learning in Science Museums," *Curator: The Museum Journal*, 39, no. 2 (1996): 123-138.

[3] Rolf Steier, Palmyre Pierroux, and Ingeborg Krange, "Embodied Interpretation: Gesture, Social Interaction, and Meaning Making in a National Art Museum," *Learning, Culture and Social Interaction*, 7 (2015): 28-42.

[4] Alan S. Marcus and Jennifer S. Kowitt, "Museum Footnotes: Helping Student Visitors Understand Museums," *Journal of Museum Education*, 41, no. 4 (2016): 353-362.

[5] Lynda Joan Kelly, "The Interrelationships between Adult Museum Visitors' Learning Identities and Their Museum Experiences," (University of Technology, Sydney, 2007).

[6] John H. Falk, "An Identity-Centered Approach to Understanding Museum Learning," *Curator: The Museum Journal*, 49, no. 2 (2010), 151-166.

[7] Stewart Brand, *How Buildings Learn: What Happens after They're Built* (Penguin, 1995).

Research for the Learning Lab began with small group co-creation sessions that allowed participants to express their thoughts in a tangible way, lending invaluable insights to researchers and designers.

USING HUMAN-CENTERED DESIGN TO SHAPE A NEW SPACE FOR LEARNING AT CHM

JOERG STUDENT
EXECUTIVE DESIGN DIRECTOR, IDEO

When CHM set out to design a dynamic new space dedicated entirely to learning, they turned to IDEO to help them figure out how to approach the project.

The plan to design a new Learning Lab opened up a lot of exciting opportunities for CHM: it would be possible to create entirely different experiences from what an exhibition alone could accomplish—more hands-on, engaging activities, for example, and the possibility for an enjoyable visit for learners of all ages. The Museum staff had created an impressive list of ideas and requests—a trove of inspiration—based on deep understanding of CHM's core audiences and those whom they hoped to engage, including business leaders, donors, and global supporters. This enabled IDEO to immediately start thinking about what the space could look like and what furnishings and tools might support the many suggested activities.

The Museum's leadership also hoped the new space would attract less familiar audiences who might not think of CHM as a cultural destination for them. IDEO used this goal of increased diversity as a starting point for our research. Our assumption was that if we learned directly from these prospective new audiences why CHM wasn't on their radar and how it could become attractive to them, we could help the Learning Lab make the Museum more accessible and relevant for everyone.

IDEO is a global design company and a pioneer in human-centered design. The most valuable inspiration for our designs often comes from "extreme users"—people whose needs may not be easily met without special consideration. We covered one extreme: "heavy" CHM users, represented by Museum staff and core audiences. So we needed to complement this with input from the other end of the spectrum: people who seemed like a good fit for the Museum, but who had not yet found a compelling way to participate. For this part of the process, we focused on the broader audiences the Museum was having challenges engaging in their education programs. These included teachers of non-STEM subjects in schools with diverse student populations and leaders from organizations that support local youth from a variety of communities.

The research involved hosting two co-creation sessions with approximately 30 people each. Co-creation sessions allow participants to express their thoughts in a tangible way, which lends invaluable insights to researchers and designers. Each of our sessions started with a brief "treasure hunt" in the galleries to familiarize participants with the Museum. Participants were encouraged to make notes of what might be interesting and what might present challenges to their students and communities. This was followed by a series of immersive, small group activities focused on three topics: space, communication, and tools. The groups were presented with cards that described a range of spatial configurations, atmospheres, furnishings, and learning tools, and asked to explain their preferences and the reasoning behind their choices. They also considered the working styles, communications, and teaching methods that might unfold in the Museum and the Learning Lab. These methodologies enable researchers to better design for users' needs and allowed us to understand visitors' emotional journeys when visiting CHM.

During co-creation sessions, participants were presented with a number of options on space configuration, communication, and tools, and then asked to prioritize and present their preferences.

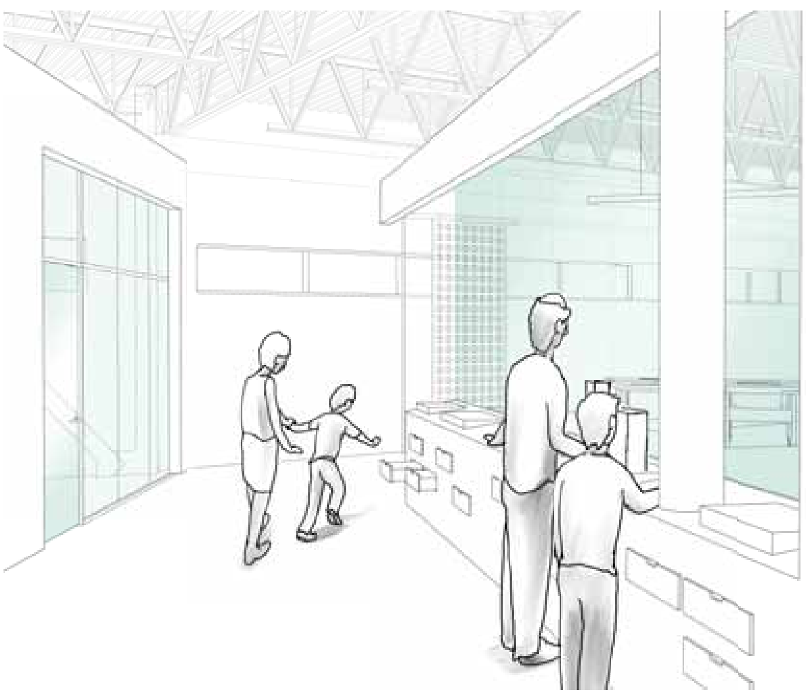
Feedback during the co-creation sessions helped us establish a "sequence of focus," a design principle that visually guides people through their experience in different ways. Since the Learning Lab aims to attract as many self-guided visitors as possible from the neighboring exhibition, *Make Software: Change the World!*, it was important to consider a hook—an interesting interaction—that would draw people into the space and encourage further engagement. The hook could be visual, employing bold graphics to incite people's curiosity. Or it might involve placing activities near the entrance that appeal to different interests, such as tables with seating that contain artifacts for close, hands-on inspection, alongside display cases showcasing historical objects for casual viewing. In this way, one sequence of focus could be narrow, directing attention toward a concentrated activity, while another could be lighter and more exploratory, both meeting the needs of different visitors and both leading them into the space.

We also uncovered important insights about the complex logistics of a field trip, and the enormous task of trying to gather a group of lively students to help them focus and learn during their visit. Teachers pointed out that while stimulus is important for attention and learning, a museum environment can be overwhelming or even stressful for some students. So for group visits, we designed a special entrance that allows Museum staff and group leaders to keep everyone together and even forgo the *Make Software* gallery altogether. Once inside the space, we designed with the need to orient students, direct their attention, and support active learning.

In addition to these insights, we learned that it was important to set a tone that felt welcoming to a broad swath of CHM visitors. There is a perception—and certainly some truth—that the history of computing is attributed exclusively to white men. In our research, we found that other groups, including women and people of color, didn't find role models or relevant access points into computing history. One of our research activities involved asking co-creation participants to pick their dream instructor for an imagined visit to the Learning Lab, from among a diverse set of possibilities. Former First Lady Michelle Obama, basketball great Steph Curry, and college students wearing San José State University sweatshirts were clear favorites, not because of their expertise in teaching, computing, or history, but because they reflect and represent the visitors who will make use of this space.

Our research led us to develop four overarching design principles: set the tone for play, provide a sequence of focus, enable a variety of learning modes and trajectories, and inspire a tactile approach to learning. Using these, we proposed a number of hypothetical environments—the "library," filled with learning resources, technology, and plush seating; the "cabinet of curiosity," with bold colors, interactive exhibits, and movable walls—and others, each of which emphasized the design principles to varying degrees. Ultimately, we created a concept that incorporated elements from all of these. Additional design recommendations were inspired by CHM's need to conduct different types of programs in the space: playful arena seating for big group gatherings and live events, flexible furniture for dynamic workshops, the ability to divide the space into sections and lead multiple programs simultaneously, and exhibits that encouraged hands-on learning and social interaction for drop-in visitors.

We are proud to have played a role in the design of the Learning Lab and we are excited to see how it will inspire CHM's diverse audiences to shape the future of technology in Silicon Valley and beyond.



IDEO presented hypothetical environment designs for the entrance to the Learning Lab, including a "library" filled with learning resources, technology, plush seating, and a "cabinet of curiosity" with interactive exhibits and movable walls.

07.2

It was a day that captivated the imagination of millions around the world.

0.69

On July 20, 1969, Ohio native Neil Armstrong ventured from the confines of the Apollo 11 lunar module and took humankind's first steps on the Moon. Engineers and astronauts were hailed as heroes, while images of space consumed popular culture, from science fiction novels to television shows to cereal boxes. A half-century later, the wonders of space are the subjects, battlegrounds, and resources for a new generation. As humanity celebrates the 50th anniversary of the Moon landing, we delve into the history, the technology, the imagination, and the future of space.

Sixteen-year-old Jimmy Blackmon meets his hero—and senior technical leader of the US Space Program—Dr. Wernher von Braun at the US Army's Redstone Arsenal in 1956. Jimmy became a national figure due to his early rocketry experiments.

BY DAG SPICER
SENIOR CURATOR

THE COMPUTING RACE TO SPACE: FROM SPUTNIK TO APOLLO

The 1956 issue of *Time* magazine carried the story of 17-year-old Eagle Scout Jimmy Blackmon, a junior in high school who had spent the last three years building his own liquid-fueled rocket. At over six feet long and capable of reaching heights of thousands of feet, the launch of Blackmon's rocket was forbidden by the Civil Aeronautics Administration when made aware of it. The rocket nonetheless made the news nationally and got Jimmy a one-on-one interview with German-American rocket scientist and public face of the US space program Dr. Wernher von Braun.[1] He also did manage to launch a (much safer) solid-fuel version of rocket, discretely, on the North Carolina waterfront later that year.

Blackmon became an actual rocket scientist, graduating with a PhD in mechanical and aerospace engineering from UCLA in 1972 and teaching for 40 years at the University of Alabama in Huntsville. His path from boyhood onward is symbolic of the aspirations and challenges of the Space Race and how it entrained an entire nation on a project of mass science and technology development and education. Since the announcement of the Truman Doctrine and the institution of the Marshall Plan in 1947, the nation was at war with the Soviet Union—a Cold War—and one of the new battlefields was space.

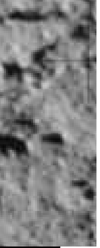
Blackmon's rocket coincided with the launch of the Soviet's Sputnik satellite that same year. The successful launch of Sptunik represented what many feared could become "a technological Pearl Harbor."[2] Technology and science became the weapons of choice in this new contest: it was not just the number of missiles a nation possessed that mattered, it was also the number of scientists and engineers. The moral panic resulting from a feared "knowledge gap" between Russian and American schoolchildren fostered massive government investments in programs (at both state and federal levels) to update science education across the country. Engineers, in particular, were portrayed as modern heroes, applying their specialized knowledge for both the protection of the United States and its allies as well as for the benefit of humanity.

It was also at the time of Sputnik when electronic digital computers began to be used in earnest by an ever-widening circle of users. In the late 1950s, computer systems were usually room-size mainframe systems, costing millions of dollars to purchase and operate. By the mid-1950s the industry had bifurcated from "number crunchers" into scientific and business users. Scientific customers needed high-speed binary floating-point capability and would typically use the FORTRAN programming language; business users opted for decimal-oriented computers optimized for dealing with financial or text information. These enormous devices could be rented to save money but even then, to have access to an electronic computer put one at the very forefront of science. The new space program would make ample use of this technology.

It's no coincidence that the former National Advisory Committee for Aeronautics (NACA) was renamed the National Air and Space Administration (NASA) the year after Sputnik. NASA's new role was to help reorient the nation's scientific and industrial resources to the space program. In the words of NASA Director Hugh Dryden:

> *It is of great urgency and importance to our country both from consideration of our prestige as a nation as well as military necessity that this challenge [Sputnik] be met by an energetic program of research and development for the conquest of space…It is accordingly proposed that the scientific research be the responsibility of a national civilian agency…*[3]

COURTESY OF DR. JIM BLACKMON



As an institution that performed a lot of routine calculations, NASA was an early and enthusiastic adopter of electronic computers, both digital as well as their earlier analog counterparts, some of which were still very useful in conducting simulations. By the time of the Apollo program's first flight in 1966, nearly all aspects of the mission were under control or supervision of computers: mission planning, rocket countdown and launch, guidance, navigation, control of the spacecraft itself, telemetry and tracking, touchdown on the Moon, and return to Earth. Apollo built on the success of two prior US rocket programs: Mercury, which sent single astronauts into orbit around Earth; and Gemini, which sent two astronauts together into orbit to understand how spaceflight affects humans, how to do a spacewalk, and how to connect two spacecraft together. All of these steps in the Mercury and Gemini programs were geared toward providing technologies and procedures for Apollo.

The planned Apollo mission relied on computers of all sizes and types: from large scientific mainframes, like the IBM 7090/7094, to legions of smaller computers, like the IBM 1401 series, and even early single-user computers, like the Librascope LGP-30 and the Bendix G-15. At its peak, the program had over 400,000 employees and contractors, each dedicated to a specific mission or task. Mission-critical calculations depended on great coordination between departments, employees, companies, and machines. Naturally, all the computers were Earthbound; it would take a special effort to bring computing to the spacecraft themselves.

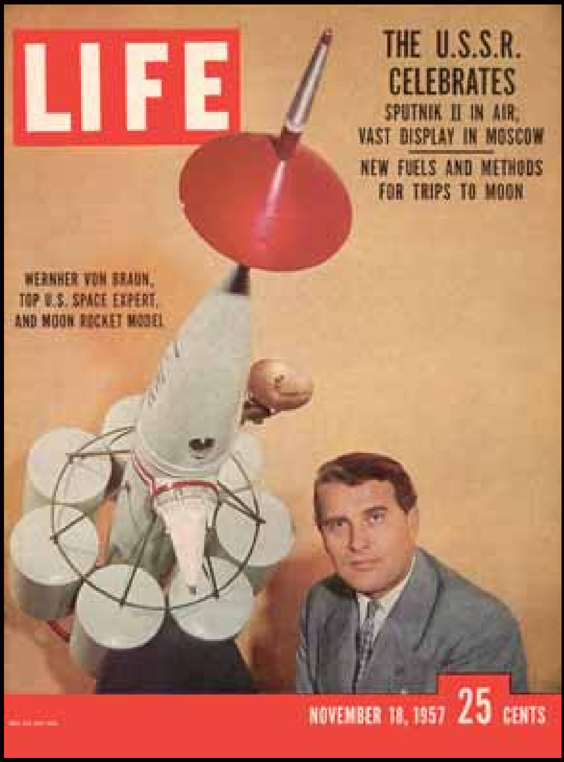
There were two main computing systems used onboard the Apollo spacecraft. The first was the Apollo Guidance Computer (AGC), originally a room-size set of seven-foot-high racks filled with electronics, which was eventually compressed into a single 70-pound box and controlled through an operator panel known as the Display Keyboard (DSKY). The AGC was a remarkable development for several reasons: 1) it compressed the AGC circuitry by hundreds of times using the then new technology of integrated circuits (ICs); and 2) its software was "man-rated," meaning it was reliable enough to be used in a real mission with living people, a first for computer science. Built by Raytheon, the AGC was one of the earliest and largest users of ICs, providing real-time guidance and control to the spacecraft (both the lunar module and the command and service module had an AGC), a virtual electronic lifeline to the astronauts.

The second computer receives far less attention. Known as the instrument unit (IU), this computer-controlled system was physically arrayed around the circumference of the Saturn V rocket launch vehicle's third stage. The IU provided the guidance and stage sequencing system for the rocket and was designed by NASA and IBM. It comprised multiple sensors such as accelerometers, gyros, pressure and temperature sensors, and a radar tracking and command radio system, among other capabilities. Parts of the IU were actually based on the Nazi V-2 rockets of WWII. The main computer in the IU was the Launch Vehicle Digital Computer (LVDC) designed and built by IBM's Electronic Systems Center in Owego, New York. Simple by today's standards, the LVDC was the "autopilot" for the Apollo rocket from launch to Earth orbit insertion. While the LVDC and AGC ran at only a couple of megahertz in terms of clock speed, it was the outstanding reliability of the systems that made them the right choice. Similarly, the multiyear development cycles of such projects, sometimes a decade or more in duration, usually prevent the most recent technologies from being chosen for a mission in the future.

The Space Race, roughly 1957 to 1977, was one of the great dramas of the 20th century. Like World War II before it, the contest's two adversaries deployed national programs of scientific and technical development in a trial of competing political systems and, ultimately, ways of life. Despite this somber backdrop, the era of Apollo was a time of immense excitement and optimism—on both sides of the Iron Curtain. Space seemed limitless and became the chess board on which a new battle of wills and ideologies was played out, one in which the combatants were not soldiers but engineers. The computer was at the side of these modern day Prometheans every step of the way to the Moon and back.

Close-up of Soviet Sputnik satellite, 1957. The launch of this small sphere in October of that year inspired fear and panic in the US about American technical capabilities, leading to the creation of the National Defense Education Act and NASA.

NASA astronaut Buzz Aldrin sets up the Early Apollo Scientific Experiments Package in this photo by Apollo 11 commander Neil Armstrong on July 20, 1969, after their historic Moon landing.



Dr. Wernher von Braun in front of a rocket model on the cover of *Life* magazine, only three weeks after the launch of Sputnik and one week after Sputnik II, which carried the dog Laika into orbit.

TOP RIGHT: NASA / BOTTOM LEFT: PHOTO BY RALPH CRANE/THE LIFE PREMIUM COLLECTION/GETTY IMAGES

View from Neil Armstrong's position in the lunar module seconds before the touchdown of Apollo 11. This image was made by Industrial Light and Magic visual effects supervisor John Knoll. The "1202" error from the AGC—indicating an overflow condition—can be seen to the lower right.

COMPANION TO THE STARS: THE APOLLO GUIDANCE COMPUTER

BY DAG SPICER
SENIOR CURATOR

In August 1961, NASA contracted with the Charles Stark Draper Lab at MIT, which had already designed digital computers for space with its 26-pound, 0.4-cubic-foot on-board guidance computer for the United States Navy's Polaris missile.

The Apollo Guidance Computer (AGC) project was radically ambitious. According to hardware design team lead Eldon Hall in a 1982 lecture at the Boston Computer Museum:

> If the designers had known then what they learned later, or had a complete set of specifications been available as might be expected in today's environment, they would probably have concluded that there was no solution with the technology of the early sixties.[1]

The main contractor for the AGC was defense contractor Raytheon at their Sudbury, Massachusetts, division. When initial research and planning began in late 1959, the Draper Lab began experimenting with ICs—a new technology that combined multiple transistors into a single package. ICs provided enhanced reliability, much lower power consumption, and took up less space.

Another technology embedded in the AGC was rope memory, essentially core memory with the windings hard-wiring a zero or a one in each bit location. The information stored in rope memory could be changed, albeit at great cost and effort. To wire rope memory involved painstakingly threading wires the width of a human hair through the tiny magnetic cores of the memory.

Meetings of the guidance and navigation software team, led by 2017 CHM Fellow Margaret Hamilton, were often called "Black Fridays" because the bar for accepting any changes to the Apollo code was very high, resulting in many tense meetings and code reviews.

From the user perspective, the AGC was designed to be simple. Nonetheless, in a typical Apollo mission, astronauts had to enter 10,600 keystrokes into the AGC. This was made simpler through a special interface called a Display Keyboard, or DSKY, in which astronauts could communicate with the computer by using a "Verb + Noun" syntax.

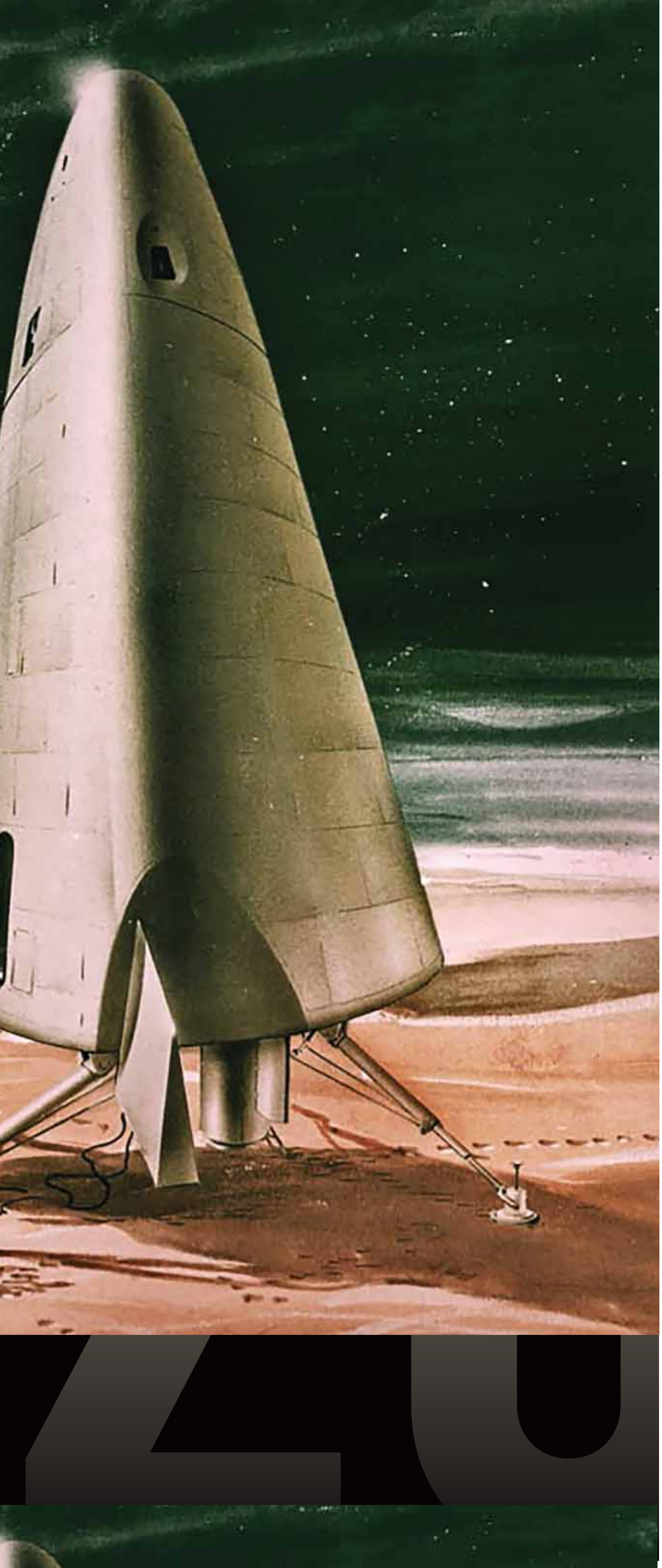
While the AGC wasn't particularly fast even compared to the minicomputers of its day, it was more reliable than commercial computers, much smaller given its performance, and it sipped a measly 70 watts of power. Not bad for putting a man on the Moon.

[1] The Apollo Guidance Computer," part one, by Eldon Hall, June 10, 1982, Computer History Museum, 102624617.

Margaret Hamilton (top), mathematician and programmer at the MIT Instrumentation Laboratory, sits in a mock-up of an Apollo command module, November 25, 1969. Hamilton led the team developing flight software for the AGC (bottom).

OPPOSITE: COURTESY OF JOHN KNOLL / THIS PAGE, TOP: COURTESY MIT MUSEUM

NASA



MAKE IT SO! SCIENCE FICTION, COMPUTING & SPACE

BY DAVID C. BROCK
DIRECTOR & CURATOR, SOFTWARE HISTORY CENTER

There is a cultural trope that computing's makers and avid users are devotees of science fiction (and fantasy, as the genres are so strongly paired). I know this devotion to be true also of historians of computing from first-hand experiences: I just finished N.K. Jesmin's *Broken Earth* trilogy (I know, I'm late to the party), and just ordered Kim Stanley Robinson's *Red Moon*. I do wonder about your relationship with science fiction, dear reader.

Even so, the body of academic studies that directly attack the role of science fiction within the history of computing is, in a word, thin. The 2011 edited volume *Science Fiction and Computing* is the exception that shows the rule, yet its emphasis is on unpacking science fiction as a cultural production. The essays examine how computing is represented in science fiction literature or film, how science fiction forecast issues that later technologists would grapple with, and, as in the work of David Kirby, how technologists create science-fictional visions of virtual reality and novel user-interfaces to build cultural support for their R&D programs.

What appears generally missing are historical studies that get at more direct connections between science fiction and the practice of computing itself. We know that early digital computing was deeply connected to military efforts, including rocketry for nuclear missiles, satellite launches, and space exploration. Space exploration and powerful computing were central themes of science fiction of the 1940s through the 1960s (and well beyond). How did these science fictional visions lead people into computing and shape their work there?

Jules Verne's legendary *From the Earth to the Moon* captured the imaginations of many, including German rocket scientist Hermann Oberth. Inspired by Verne, Oberth created his own speculative novel in 1923, *The Rocket into Interplanetary Space*. Verne's piece is reimagined in this 1953 Classics Illustrated comic.

This gap is understandable: Where are the sources? Where would one find historical records linking science-fiction fandom to the life and work of a contributor to computing? A diary? A letter? Notebook jottings? Such informal records are increasingly inaccessible, following the rise the telephone and then computer records and communications.

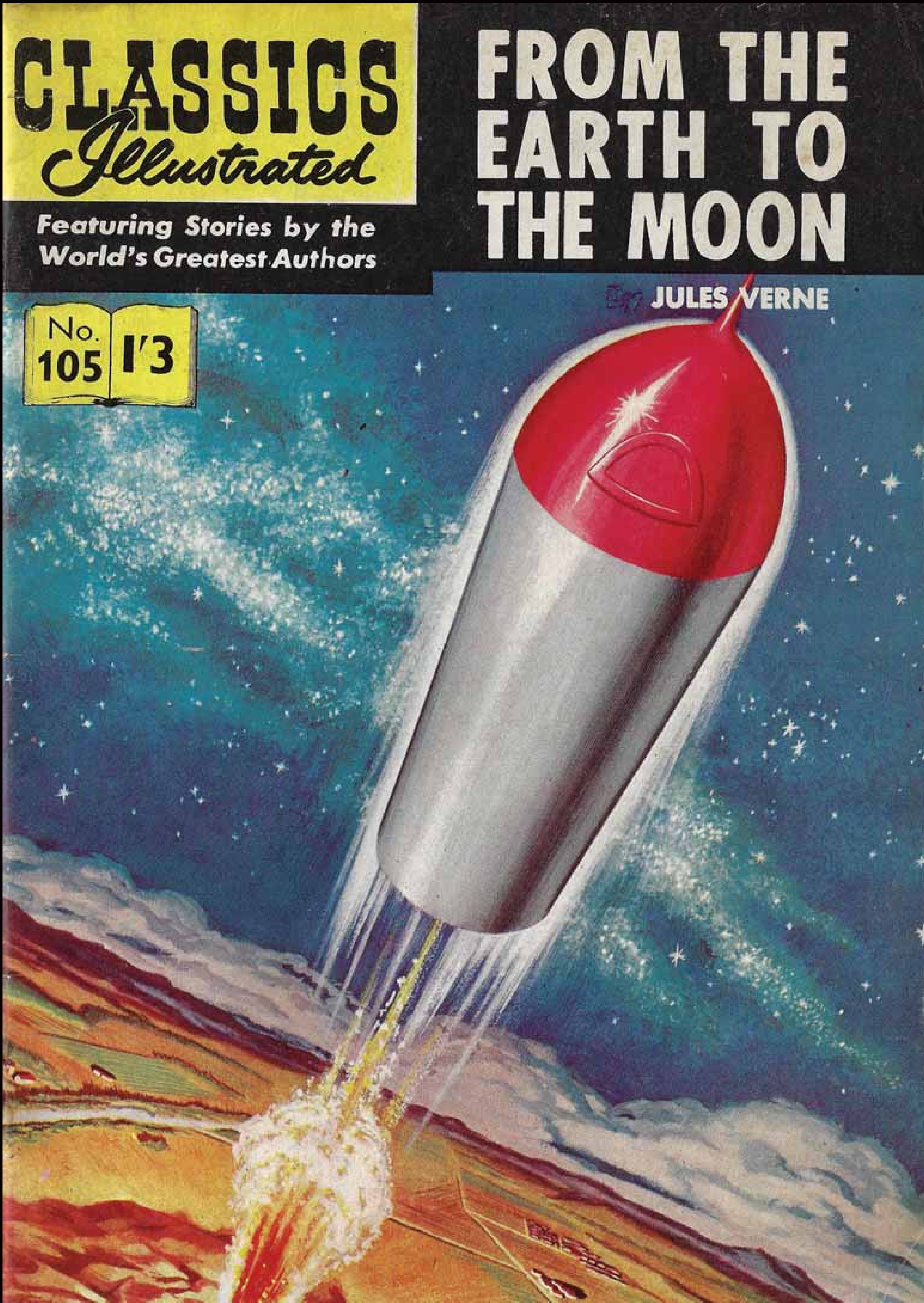
Evidence for connections between science fiction and computing in the life of an individual could be had by asking, that is, through conversations. Oral histories, then, are critical resources for academics, journalists, fans, and media producers interested in the place of science fiction within computing. The importance of oral history to recovering these connections struck me in a recent interview with software-engineering pioneer Professor Barry Boehm.[1] Boehm developed computer programs for missile design in the 1950s at Convair and RAND and went on to important roles at TRW, DARPA, and the University of Southern California. I was astonished by the connections between science-fiction fandom, thermonuclear ICBMs, and the rise of digital computers in his recollections.

The history of rocketry into the 1940s has already been linked to science fiction through the stories of German figures like Hermann Oberth and Wernher von Braun. Through interviews and recollections by Oberth, we know he was inspired by Jules Verne's science fiction story *From the Earth to the Moon* to create his own work of technical science fiction, what historian Patrick McCray has called "visioneering," *The Rocket into Interplanetary Space* in the 1920s. Oberth proposes space exploration by rocket, offering scientific and engineering calculations for achieving interplanetary travel. Oberth then led a community of rocketry developers in Germany into the 1930s.

Wernher von Braun, a protégé of Oberth's and a devotee of *The Rocket*, would do much to realize his mentor's vision through his partnership with the Nazi regime to create the infamous V-2 rocket and, later, by bringing much of his rocket group to the United States, where they were profoundly influential in ICBM and NASA developments, including the Apollo program. Like Oberth, Von Braun was inspired by science fictional visions. As noted in his *New York Times* obituary, Von Braun recalled a story read as a youth about travel to the Moon: "It filled me with a romantic urge. Interplanetary travel! Here was a task worth dedicating one's life to." Von Braun himself published work of technical science fiction, along the lines of Oberth's, in 1953 titled *The Mars Project*, laying out a detailed plan for human exploration of Mars by rocket. Indeed, to build public support for space exploration, von Braun collaborated with Walt Disney on a series of three television programs in the mid-1950s: *Man in Space*, *Man and the Moon*, and *Mars and Beyond*.

Born in 1935, Barry Boehm deeply engaged with a science fiction literature that was fascinated by exploration of Mars by rocket. Until the first Venus and Mars landers of the late 1960s and 1970s, there was widespread scientific and popular belief that both planets harbored life, quite possibly intelligent. At least as late as 1959, von Braun was certain that Mars had large swaths of vegetation, which varied seasonally, and that Mars could be among the millions of planets that he believed could contain intelligent life.[2]

Boehm's father worked for Douglas Aircraft in its manufacturing complex in Santa Monica. Attending the public high school in Santa Monica, Boehm's school life was occupied by his interest in mathematics and the tennis team. In summers, Boehm worked. His first job was at the Douglas plant, crawling inside aircraft wings during assembly to hold a metal stop against which a skilled riveter would fix a series of rivets. It was loud work, to say the least. The following summer, Boehm found a job that was, acoustically, the opposite. He worked as a page in the Santa Monica Public Library, shuffling materials from the library's stacks for patrons. The post not only gave him insider access to the science fiction literature to which he was by then highly devoted, but also chances to interact with important figures from the "Golden Age of Science Fiction" in the Los Angeles scene. Boehm recalls:


CLASSICS
Illustrated
Featuring Stories by the
World's Greatest Authors
FROM THE
EARTH TO
THE MOON
By JULES VERNE
No. 105
1'3

Yes, well, my gods were people like Isaac Asimov and Robert Heinlein and then a whole bunch of other authors. Ray Bradbury particularly lived in the Santa Monica area. One of the neat things about being a library page is that people like Ray Bradbury would come in and say, "Could you go down and get me this copy of the 1948 Santa Monica Evening Outlook?*" Or Christopher Isherwood would come in. There were a bunch of interesting people in the community that you bumped into.*

Boehm picked up on a streak in many of these science-fiction works: A tacit argument that such a future was possible, and within a lifetime. "But I really believed," Boehm recalled in the oral history, "that we were going to go to Mars and then colonize it and all that sort of thing."

Living in Santa Monica gave Boehm the chance to encounter a machine that could make real Ray Bradbury's *Martian Chronicles*, published while Boehm was in high school: the electronic digital computer. The RAND Corporation was also in Santa Monica and occasionally opened its doors to local students. Boehm was among them, talking with RAND's mathematicians and encountering its early electronic digital computer, JOHNNIAC (now on display at CHM).

As an undergraduate at Harvard, Boehm continued to be driven by the vision of humanity getting to Mars in his lifetime. He picked up a part-time job in Harvard's astronomy department, working at its observatory: "And, again, with the science fiction, the astronomical observatory was the place you could get familiar with the planets and all that kind of stuff." In his mathematical studies, Boehm gravitated toward numerical analysis, learning to program both Harvard's Mark IV electromechanical computer and its new UNIVAC I electronic digital computer. Eventually, he programmed the UNIVAC I to automate his observatory job, making the computer calculate the speeds of meteors from measurements of telescope photographs.

During high school, Boehm worked at Douglas Aircraft (bottom, right), and at the Santa Monica Public Library, where he encountered science fiction legends like Ray Bradburry of the *Martian Chronicles* and artwork that illuminated the extraterrestrial stories, like the illustration below by comic book artist Alex Schomburg.

Hermann Oberth (center, in profile) demonstrated a liquid-fuel rocket engine in Berlin in 1930. Second from the right is 18-year-old Wernher von Braun, who would become director of NASA's Marshall Space Flight Center.

TOP: COURTESY OF THE ESTATE OF ALEX SCHOMBURG / BOTTOM LEFT: SMITHSONIAN NATIONAL AIR AND SPACE MUSEUM (NASM 2003-37541) / BOTTOM RIGHT: COURTESY OF THE SANTA MONICA PUBLIC LIBRARY

In his undergraduate summers, Boehm worked with Convair in San Diego, which was then developing the Atlas rocket as an ICBM for the US Air Force. Boehm recalls:

> *[T]hey had one of the most powerful computers that was available at the time. It was a UNIVAC ERA 1103…I got introduced to the supervisor who walked me into this computer and said, "Yes, this is what we do here. We write computer programs that help us analyze rocket trajectories and rocket stability analyses and structural analyses and things like that. If you're going to be here there's one thing I want you to keep in the front of your mind, which is that we're paying this computer $600 an hour, and we're going to pay you $2 an hour. And we'd like you to act accordingly."*

After graduation, Boehm rejoined Convair—working on computer simulations of the Atlas rocket—before taking a similar position with RAND back in Santa Monica. At RAND, Boehm was key to the development of GRAPHICAL ROCKET in the mid-1960s, a rocket simulation and analysis program employing an early graphical user interface.

While working at RAND and earning his PhD at UCLA into the mid-1960s, Boehm still held onto the vision of human exploration of Mars, like others he encountered in the aerospace scene. He remembers:

> *Basically, I was still thinking we'll get to Mars somehow. The NAA [National Aeronautic Association] had a bunch of monthly meetings and was hosting a bunch of conferences. As a junior member, I would get the job of meeting senior rocket scientists at the airport and driving them to the conference or things like that. It was really a stimulating thing. Just about every big aerospace company had its German rocket scientists. General Dynamics had Krafft Ehricke who was, again, big on doing the computations of going to Mars and back. I got to interact with him and this was, again, a really stimulating kind of thing and kept you thinking that, yes, maybe we'll get there after all.*

Boehm remained engaged with science fiction until the erosion of his belief that humanity would visit Mars in his lifetime:

> *[Engagement with science fiction remained] for a while, and then the more I got into things like the space world, and people who started reporting things from Mars and Venus that said they're hard to get to and they don't look very friendly. I really still read those things occasionally, but it's more of a minor thing now.*

While his immersion in science fiction and its Mars vision eventually faded, it had brought Boehm into a deep engagement with computing, in which he would make several noteworthy contributions to software and would go on to play leadership roles in the fields of software engineering, computer science, and engineering education. Needless to say, I now ask about science fiction in every oral history I conduct. ○

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1 All quotes that follow are from the oral history of Barry Boehm, interviewed by David C. Brock and Lee Osterweil, November 17, 2017.

2 Listen to "A Conversation between Dr. Wernher von Braun and Willy Ley," June 9 and 23, 1959, New York City and Redstone Arsenal, Huntstville, Alabama: https://archive.org/details/AConversationBetweenDr.WernherVonBraunAndWillyLey.

December 2018 marked the 50th anniversary of *Earthrise*, by astronaut William Anders, an inspiration and reminder to humanity for responsible space exploration and care for Earth.


NASA

NEW DISCOVERIES, TECHNOLOGY & ETHICAL QUESTIONS: A TOUR THROUGH THE CHANGING WORLD OF SPACE

DANIELLE WOOD
DIRECTOR, SPACE ENABLED RESEARCH GROUP
MIT MEDIA LAB

If you check in with the latest news from space, it can be dizzying to keep track of the headlines, rumors, prognostications, high-cost systems, policy announcements, celebrity entrepreneurs, and government programs. The future of space is exciting, but there's work to do to ensure that the benefits are spread equitably and ethically around the world. While some changes promise greater access to space technology that can help people around the world, others bring important ethical questions about how humans can expand their presence in space while rejecting a colonial mindset. Let's take a brief tour through the changing world of space.

Earth from Space

One of the biggest reasons we go to space is to learn about Earth. For the past four decades, government agencies in the United States, Europe, Japan, India, China, Brazil, Argentina, Canada, South Korea, and other regions have operated nationally owned Earth science satellites that monitor changes in our environment. With their unique sensors, these satellites can measure features like soil moisture, chemical components in the atmosphere, wind speed, humidity, ocean temperature, vegetation growth, and other variables. Government-funded research agencies use this data to design online maps and other applications that can answer important questions for policymakers and citizens alike. In a project called SERVIR, NASA and the US Agency for International Development work with regional centers that serve countries in Latin America, West Africa, East Africa, the Himalayan Region, and Southeast Asia.[1] SERVIR teams in each region use NASA satellite data to build

Researchers use satellite imagery from the company Planet to identify zones experiencing rapid deforestation near the Bolivian Andes.

web applications that can inform farmers how to manage crops under cold temperatures, warn forest managers of distant fires, help experts estimate flood risks, and advise first-responders after natural disasters.

A new era of satellite-Earth observation may also be unfolding. Several commercial companies have built businesses around collecting imagery of Earth and selling images or analysis services. For example, the company Planet operates a fleet of about 200 satellites the size of a shoebox that each carry a camera.[2] With this large group of satellites, Planet can take images everywhere on Earth each day. This type of data is used for a variety of applications, and new ideas are being explored every day—from monitoring farms and understanding traffic patterns to planning construction and tracking ships.

In the coming decades, data is going to be generated by sensors in space, in the air, and throughout natural and human-made environments as the internet of things takes shape.[3] The amount of data is already overwhelming, and it is only going to grow. Researchers and companies are inventing smarter computer algorithms to answer questions hidden in large data sets.

Changing Our Definition of Life

Humanity's understanding of its place in the universe will shift forever when we find evidence of current or past life beyond Earth. It is possible that strong evidence for life on another planet or moon will be found within our lifetime. Scientists from all over the world are studying the surfaces of thousands of planets, dwarf planets, moons, asteroids, comets, and other small rocks orbiting the sun. A surprisingly large amount of liquid has already been found in the solar system, from the water at the poles of Earth's Moon and Mars to the ocean worlds, such as Jupiter's moon Europa and Saturn's moon Enceladus.[4] In the coming years, scientists who are searching for life hope to send robotic explorers to visit these oceans of water and methane throughout our solar system.

Meanwhile, beyond our small solar system, scientists are learning new ways to identify planets that orbit other stars.[5] A few decades ago, we thought that the planets surrounding our sun were unique. Now scientists have found thousands of planets orbiting other stars. We are learning how to measure what kinds of materials and atmospheres make up these "exoplanets." With new science and engineering techniques scientists are asking whether any of these distant planets could feel like home to Earthlings.

ISERV, a camera on the International Space Station, captured this image showing changes in San Quintin, the largest glacier in Chile's Laguna San Rafael National Park.

ISERV/SERVIR

Left: The NASA/USAID SERVIR team in East Africa works with farmers to create environmental monitoring systems to measure weather conditions that impact the health of tea farms. Bottom: Small satellites are being used by government, commercial, and research teams to take measurements and provide communication services.

Is Smaller Better? A New Era of Satellite Building

The way we build satellites is changing rapidly. During the 1970s and 1980s, the space community developed a method to build reliable satellites. This method includes careful testing of satellites before launch by placing them in conditions that simulate the temperatures of space, its vacuum-like environment, and the violent shaking of a launch vehicle. These traditional satellites are large, roughly the size of a sports utility vehicle, extensively tested, and designed to carry as many scientific sensors or radios as possible, all of which makes them expensive to build and maintain.

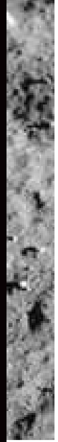
Another approach to building satellites has been emerging over the past three decades, and it's turning the industry upside down. Engineers are building smaller satellites with fewer sensors or radios that last for only a short time in space, say for one year instead of 10 years. These small satellites are designed with standard commercial electronic parts that make them cheaper to both build and test. Engineers expect to get less performance out of an individual satellite and more performance out of a group of satellites working together. Companies are already proposing new business models around small satellites, such as having a large number of small satellites flying close to the Earth and providing communication services that give internet access and phone connections to people anywhere on the globe.[6]

In the next revolution, we need to learn how to use additive manufacturing or assembly of modular components to provide satellites with designs that can be updated after launching into space. New areas of research are necessary to reduce the time satellites spend on orbit after they finish their mission. Each object in space increases the risk that satellites may collide and damage each other.

The Apollo Generation Grows Up

A generation of children was inspired when they watched the first humans explore the Moon during the Apollo missions. A few of these children include entrepreneurs Jeff Bezos, Elon Musk, Richard Branson, and the late Paul Allen, all of whom made money in non-space fields and built visionary space companies. Today, the exploits of companies like Musk's Spacex and Bezos' Blue Origin attract a new generation of space enthusiasts via social media. For example, Spacex is well known for videos of their rockets launching and returning vertically on land or on floating sea platforms.[7] These founders also advocate visions for how humans can expand our activities in space. Spacex and Musk are preparing to create neighborhoods on Mars with all the functions of an Earth-based society,[8] while Bezos and Blue Origin are working toward a future with "millions of people living and working in space."[9]

LEFT: RCMRD/SERVIR-EASTERN & SOUTHERN AFRICA / RIGHT: NASA



In the future, entrepreneurs may send robots to asteroids to extract water or metals. Companies may build manufacturing systems in orbit around the Earth or the Moon that can create products for markets on Earth or in space. If many people, or robots, are working in space, we may need fuel depots, communication, waste management, agricultural production, social venues, and cultural institutions, either in orbit or on planetary surfaces such as the Moon. As this new space activity is considered, more international coordination is needed to ask what guides our economic activities in space. There are already five United Nations Treaties that have been signed by many countries.[10] Now is the time for society to examine how we can expand human presence in space while increasing economic equality, reducing social hierarchy, celebrating cultural diversity, and avoiding neo-colonial behavior in which powerful actors control territory or resources at the expense of the less powerful.

A Growing Space Community

How will this new scientific and commercial activity in space impact people who live all over the world, especially those who have not been traditionally involved with shaping what happens in space? Countries around the globe are establishing national space programs, training space engineers, and operating satellites for Earth observation or communication. Recently, countries such as Ghana, Kenya, the Philippines, Bhutan, Costa Rica, Chile, and Mongolia completed their first satellite projects, while countries such as Mexico, South Africa, Singapore, Brazil, Argentina, Nigeria, Malaysia, Turkey, Vietnam, Indonesia, and others have a long record of satellite projects. These countries use satellites primarily for Earth observation applications and communication services. While many of the entrepreneurial companies in space have been based in the United States, there are plenty of examples of new space companies in Europe, Asia, Latin America, and Africa.

As new adventures open up in space, innovative ideas are needed from every part of the globe to bring the benefits of space to everyone on Earth. ○

About the Space Enabled Research Group

The mission of the Space Enabled Research Group is to advance justice in Earth's complex systems using designs enabled by space. Our message is that six types of space technology are supporting societal needs, as defined by the United Nations Sustainable Development Goals. These six technologies include satellite Earth observation, satellite communication, satellite positioning, microgravity research, technology transfer, and fundamental scientific research. The Space Enabled Research Group is part of a large network of government agencies, international organizations, nonprofits, entrepreneurial startups, and universities that work to increase the opportunities to apply space technology in support of the Sustainable Development Goals.

[1] SERVIR, "SERVIR Connects Space to Village," https://www.servirglobal.net/. Accessed December 7, 2018.

[2] Planet, "Homepage," https://www.planet.com/. Accessed December 7, 2018.

[3] Jacob Morgan, "A simple explanation of 'The Internet of Things'," May 13, 2014, https://www.forbes.com/sites/jacobmorgan/2014/05/13/simple-explanation-internet-things-that-anyone-can-understand/#57228bc91d09. Accessed December 7, 2018.

[4] https://www.nasa.gov/specials/ocean-worlds/

[5] National Aeronautics and Space Administration, "Exoplanets," https://exoplanets.nasa.gov/. Accessed December 7, 2018.

[6] This has been done with larger satellites with the Iridium constellation, but the price of the service has been so high that it was mainly used by wealthy or commercial customers.

[7] Space Exploration Technologies, "SpaceX YouTube Channel," https://www.youtube.com/channel/UCtI0Hodo5o5dUb67FeUj-DeA. Accessed December 7, 2018.

[8] Dave Mosher, "SpaceX has published Elon Musk's presentation about colonizing Mars..." https://www.businessinsider.com/elon-musk-mars-iac-2017-transcript-slides-2017-10. Accessed December 7, 2018.

[9] Tamara Chuang, "Jeff Bezos want to open the way for millions to live, work in space," *The Denver Post*, April 12, 2016, https://www.denverpost.com/2016/04/12/jeff-bezos-wants-to-open-the-way-for-millions-to-live-work-in-space/. Accessed December 7, 2018.

[10] United Nations Office of Outer Space Affairs, "Space Law Treaties and Principles," http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties.html. Accessed December 7, 2018.

Interface Message Processor (IMP), ca. 1969. This refrigerator-size unit served as the interface between the early ARPANET and a host computer connected to the network. Inside the hardened military case is a Honeywell 516 minicomputer. Cost: $82,200.

© MARK RICHARDS/COMPUTER HISTORY MUSEUM, X105.82

ORAL HISTORIES

HAPPY NETIVERSARIES! THE WEB TURNS 30 AND CYBERSPACE TURNS 50

BY MARC WEBER

CURATORIAL DIRECTOR, INTERNET HISTORY PROGRAM

The end of the 1960s was the "Big Bang" for the online world, or as it was later called, cyberspace. In late 1968 and then a year later, Doug Engelbart's lab publicly demonstrated their ONLine System with many of the user features familiar today: clickable links, videoconferencing, email, online collaboration, and so on. Andy van Dam was helping Ted Nelson prototype parts of his vision for a remarkably overlapping set of features. Popular articles speculated about "computer utilities" for home shopping, news, email, even tracking and selling mass user data(!).

Hot new startups like Tymshare and LEXIS offered limited online features to business users, while experimental systems at Dartmouth, MIT, and the University of Illinois served students. Meanwhile, several groups around the world were developing cheap, general-purpose networks to help carry such features far and wide. Among them was ARPANET, developed by the same military research agency that funded Engelbart's and other online efforts. The excerpt below tells the story of how it got hooked up in October 1969, a few months before rivals in the United Kingdom and elsewhere turned the key. ARPA's family of networks would later birth the particular internet protocols we use today.

But instead of quiet progress, the next 25 years would be consumed by bitter standards wars at every level of the online world, until the eventual winners emerged from the chaos: Ethernet for local connections, ARPA's Internet protocols for distant ones,[1] and the web as the main online system for navigating information over those connections.

This year marks the 50TH anniversary of that "Big Bang," with the ARPANET's start as a well-known reference point. 2019 also marks the 30TH anniversary of the web's conception, and shorter anniversaries for everything from mass Wi-Fi to familiar giants like Amazon and Facebook.

Charley Kline (left) and Bill Duvall (right) in front of the interface message processor at CHM in 2009.

On October 29, 1969, two young programmers connected over a new sort of network: ARPANET. One was at Engelbart's lab near San Francisco, the other at UCLA. The excerpts that follow are from an interview with Bill Duvall and Charley Kline, 40 years later, at CHM.

Marc Weber: I'm Marc Weber, of the Computer History Museum, and I'm here…with Bill Duvall and Charley Kline, who…were the two ends of the first transition over the ARPANET nearly 40 years ago. So Charley, what was your role in that first transmission?

Charley Kline: Well, I was a student at UCLA at the time, and I was working in the group at UCLA that was developing our end of the hardware and software interface to make this work. And I was the one who was writing the programs on our computer to talk to the ARPANET and my end of the role, on this first communication, was trying to get that software to work, so that I could log in from a terminal on my computer, to the terminal [the system] that Bill was running at SRI.

Weber: And so you were…

Bill Duvall: Well I was the architect and the implementer of the software on the SDS 940 [computer] at SRI that basically, you know, was connecting to the Sigma 7 [computer] at UCLA. Basically we had these headsets on, these old fashioned—you know, in the old AT&T operator, AT&T telephone ads, you always saw the operator with the big headset on one side, and earphone on one side—and we had those on and we were talking to each other.

And then…you tried to connect to the SDS 940. […] [Charley] started up his software and I started up mine, and there wasn't anything that came up on the screen that said, you know, log in, or enter your user name, it was just a—his particular system just prompted, I think, with a caret [symbol], and there were a few commands you could type before logging in.

Kline: And so I typed the L, and he said he got the L, and his system took it, sent it back to me to print on my terminal. My terminal printed the L. And I said, "Great, I got the L back." And I typed the O, and the same thing. And then I typed the G, and he said, "Wait a minute, my system crashed." And it turned out he had a real minor error. At that particular level down in the bowels of the code, he wasn't expecting multiple characters from that particular point. So when it tried to type out, G-I-N, he crashed. So he told me he'd call me back in a half an hour, or an hour, or whatever, when he fixed the bug.

Weber: So you had to reboot your machine completely, and—

Duvall: Yeah, I had to rebuild it, actually. Yeah, I had to relink the operating system, I had to rebuild the operating system, change the buffer size, rebuild the operating system and then reboot it. And fortunately, it was—I mean, it didn't take a long time. It was probably 10 or 15 minutes, I would guess.

Weber: So the first word was LO.

Kline: The first word as far as—I had typed L-O-G, but the only thing that printed on my terminal was L-O.

Weber: Like "lo and behold."

Kline: There you go, right.

Weber: And how much—what did this mean to you guys at the time?

Kline: Well, when it worked, to me, it meant, "Oh, neat, we got it working." But that was the same kind of feeling I would get when I got any program working. I didn't recognize it as anything unique, or momentous. I didn't go out and celebrate. […]

Duvall: The bigger picture is that getting the network running was not a goal in and of itself. It was a piece that we needed for other research that we were doing, which was basically making a, you know, we wanted to have the idea of a computer network, with connected computers and exchange information. […] Quite honestly, at the time, the most important thing about it was, you know, that's finished, now I can go have a burger and a beer.

Kline: At UCLA, over the next several days, I showed it to people, like John Postel, Steve [Crocker], and Vint [Cerf], Len [Kleinrock]. Len wasn't in the room. I think he may think he was, but he wasn't in the room when this was happening.

Weber: Anything else either of you would like to add?

Kline: I couldn't live without it. Both because of my career, but I mean I'm just so dependent on the internet in my daily life.

Weber: Me, too, and thank you, both of you for getting it started.

Duvall: Well, I think, you know, I mean, I know Charley feels this way, and I certainly do, that you know, there's an enormous number of people that have worked on the internet, you know. I mean, we've maybe put a little pebble in place, but the people who deserve all the credit are the people who have—you know, this huge group that, starting from, when the first—when the project was first conceived, to today.

Kline: Yeah, this has been such a collaborative effort by so many people, that there's no single individual who you can say, "That's the person who made it happen." Maybe, to some degree, Bob Taylor for deciding to go off and build it and funding it, but the technology and the work of so many people involved in this to make it all happen.

Weber: But you guys were lucky enough to be able to turn the key.

Duvall: You know, it's a real honor to be able to look back and say that.

[1] The battles between GSM and CDMA for a wireless networking standard were another front.

1989: THE WEB'S CONCEPTION

BY MARC WEBER
CURATORIAL DIRECTOR, INTERNET HISTORY PROGRAM

By 1989 the internet had effectively won the battle to connect the world's networks. But because it was non-commercial, and for geeks, nobody had bothered to port easy-to-use online systems like Minitel or CompuServe to run over it. How could ordinary folks navigate the internet? A number of small players tried to fill the gap.

One of the more obscure attempts came out of CERN, the huge particle physics laboratory in Geneva, Switzerland. In March of 1989, an English physicist turned programmer named Tim Berners-Lee proposed a system that was a sort of super translator for other systems. It could link together a rat's nest of incompatible resources over the net—databases, specialized online systems, documents and media in different formats, and more—and display them on simple, standard pages. To navigate, all the user needed to do was click on links and search on keywords. It was also easy for those users to add their own links and create their own documents—gradually assembling a "web" of linked knowledge.

That proposal wouldn't become a prototype for a year and a half, and the web that eventually took off would be a simplified version of Berners-Lee's original vision. But this is where it started.

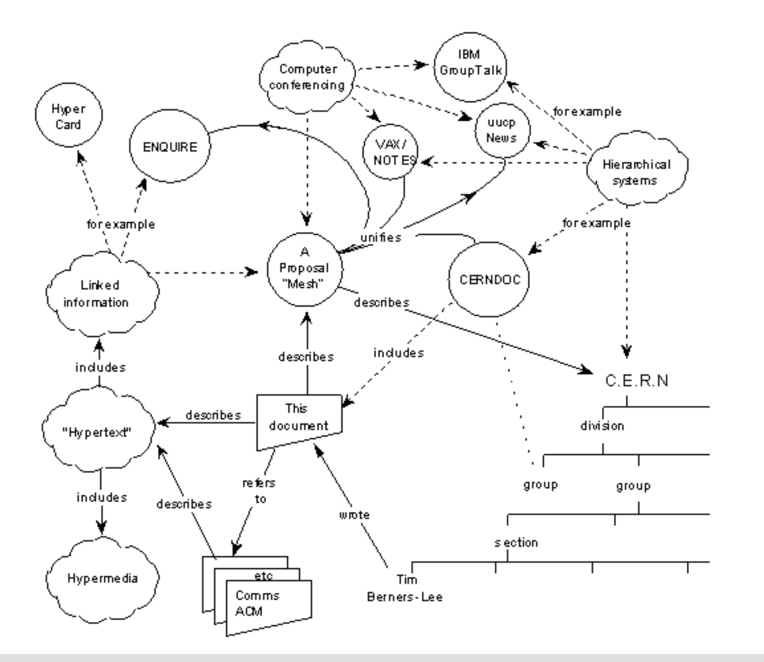


Diagram from "Information Management: A Proposal" by Tim Berners-Lee, March, 1989. He resubmitted it some months later with colleague Robert Cailliau.

COLLECTION

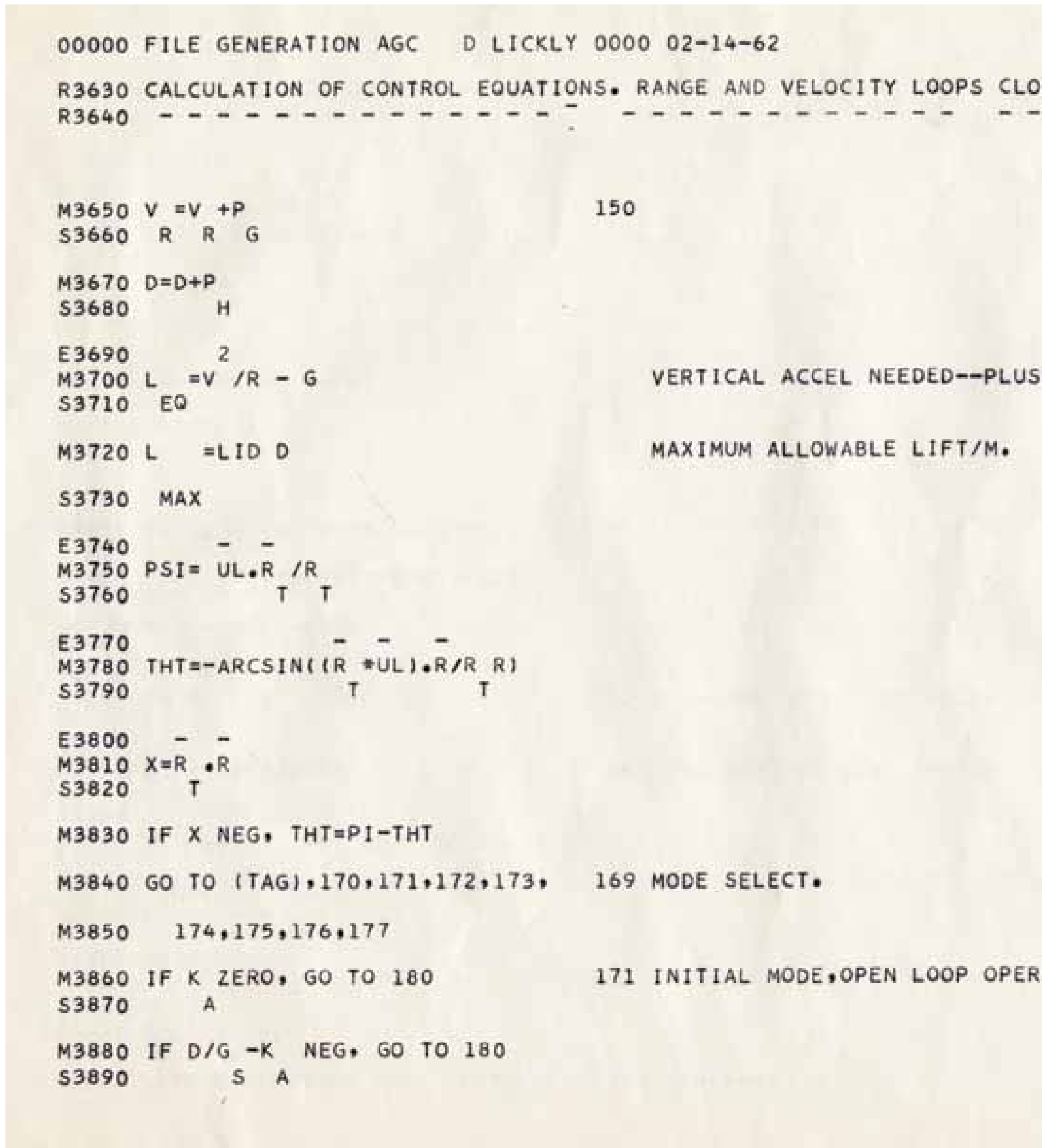
FEATURED ARTIFACTS

BY DAG SPICER
SENIOR CURATOR

SOFTWARE DEVELOPMENT RECORDS FOR THE APOLLO GUIDANCE COMPUTER, US

CHM#: 102785203, X8429.2018
Date: 1962–1963
Donor: Gift of Dan Lickly

Dan Lickly was a key contributor to and project manager of software development for the Apollo Guidance Computer, which controlled both the command and service module and lunar module of the Apollo spacecraft through launch, travel to and from the Moon, and reentry. Lickly donated records from this work to the Museum in 2018, including source code listings and reports generated by software used to develop the final algorithms and code. This example shows the results of a 1962 study of how instrument errors could derange the computation of position. Here, the formulae are represented in the three-line encoding of the MIT Algebraic Compiler (MAC) developed in the same MIT laboratory responsible for the Apollo code. In it, a top line contains information about exponents, a main line contains variables and operations, and a bottom line contains information about subscripts. In addition to this donation, the Software History Center recorded an oral history interview with Dan Lickly. ○



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M3670 D=D+P
S3680      H

E3690      2
M3700 L   =V /R - G                        VERTICAL ACCEL NEEDED--PLUS
S3710  EQ

M3720 L    =LID D                          MAXIMUM ALLOWABLE LIFT/M.

S3730  MAX

E3740      -  -
M3750 PSI= UL.R /R
S3760           T  T

E3770              -   -    -
M3780 THT=-ARCSIN((R *UL).R/R R)
S3790                T        T

E3800   -  -
M3810 X=R .R
S3820    T

M3830 IF X NEG, THT=PI-THT

M3840 GO TO (TAG),170,171,172,173,    169 MODE SELECT.

M3850   174,175,176,177

M3860 IF K ZERO, GO TO 180            171 INITIAL MODE,OPEN LOOP OPER
S3870      A

M3880 IF D/G -K  NEG, GO TO 180
S3890        S  A
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BURROUGHS SLIDE COLLECTION, US

CHM#: 102785202, X8526.2018
Date: 1957–1960
Donor: Gift of Gordon Crago

After decades as the leader in mechanical calculators, Burroughs Corporation became a significant player in computing after acquiring ElectroData Corporation in 1956. ElectroData's main product, the Datatron 205 mainframe computer, was designed by computing legend and 2013 CHM Fellow Harry Huskey and used vacuum tubes and a magnetic drum for memory. The Datatron 205 cost $135,000 at the time and was used in both military and civilian applications, including banking. Following the purchase by Burroughs, the machine was rebranded the Burroughs 205, or B205, and sold very well, with more than 100 units delivered by 1961.

This set of slides features a sales presentation for many late 1950s products by Burroughs, including the 205 computer and its peripherals, along with vintage snapshots of these devices in use and their assembly by Burroughs plant workers. Most of the photos come from the Burroughs plant in Pasadena, California, a factory which had originally been ElectroData's headquarters. ○

MANCHESTER BABY INSTRUCTION SET & FIRST PROGRAM: INTERVIEW OF TOM KILBURN, UK

CHM#:102738561 & 102780973, X8282.2018
Date: March 29, 1996 (interview)
Donor: Gift of Dr. Cliff Jones

In 1948 English electrical engineers Tom Kilburn and F.C. ("Freddie") Williams built a computer test bed—called "Baby" due to its basic nature—and successfully ran a computer program on it using their new memory invention, the Williams-Kilburn Tube.

This new memory was based on an existing cathode ray tube but used a "pick-up plate" on its face to detect tiny charges being written to its surface; charges in the form of dots (for a "1") or non-dots (for a "0"). By detecting, amplifying, and recirculating these miniscule signals, the system formed a random access memory for their rudimentary computer.

The Baby is often credited with being the first electronic, digital stored-program computer to actually run a program. In these two original and unique recordings of Dr. Tom Kilburn, who is also a 2000 CHM Fellow, he describes the instruction set of the Baby and the first program. ○

DONOR PROFILE

HARLAN E. AND LOIS J. ANDERSON FAMILY FOUNDATION SUPPORTS LIFELONG LEARNING AT CHM

BY MICHELLE FOSTER
DIRECTOR OF PHILANTHROPY,
EXPONENTIAL CENTER & GLOBAL PARTNERSHIPS

Harlan Anderson and daughter, Susan, in Monterey following a visit to CHM in early 2018.

Harlan Anderson started with humble beginnings. It was only due to the encouragement of Lois Kahl, his junior high school sweetheart, that he pursued college. Higher education was something he never imagined possible given his family's limited resources. Little did he know that this would become an instrumental time in his life and shape his philanthropic giving. In February 2018, the Harlan E. and Lois J. Anderson Family Foundation provided CHM with a $1,000,000 gift for the Museum's new Learning Lab, opened in March 2019. The focal point of the lab is the Harlan E. Anderson Arena, in recognition of the Anderson Family's generosity.

It was at the University of Illinois in 1950 that Anderson first became interested in computers while taking programming courses for the ILLIAC I computer, taught by legendary computer scientist David Wheeler of Cambridge University. That same year Harlan and Lois were married and enjoyed 66 years of marriage before Lois' passing in 2017.

After leaving Illinois in 1952 with BS and MS degrees in physics, Anderson joined the MIT Lincoln Laboratory in Cambridge, Massachusetts, before cofounding Digital Equipment Corporation (DEC) with Ken Olsen, who had been his first boss at Lincoln Labs. DEC at its peak was the second largest computer company in the world. Anderson went on to serve as director of technology for Time Inc. and spearheaded their evaluation of the future of print media during the explosion of television.

Early on, Anderson was active in professional societies and was the general chairman of the Eastern Joint Computer Conference in 1966. With personal assets, Anderson helped provide early stage financing for over 20 small technology companies. He was a trustee of Rensselaer Polytechnic Institute for 16 years and provided endowment funding for the Lois J. and Harlan E. Anderson Center for Innovation in Undergraduate Education there. He was a member of the Board of Advisors of the College of Engineering at the University of Illinois, providing endowment funding for its Lois J. and Harlan E. Anderson Laboratory for Global Education in Engineering.

Anderson's support of CHM came from his commitment to ensuring that everyone has access to quality educational programs. "He believed that his own access to education dramatically changed his life and that education has the transformative power to improve the human condition for everyone," said his daughter, Susan.

The Anderson's children, Susan, Brian, and Gregory, oversee the Harlan E. and Lois J. Anderson Family Foundation. "The title of my father's book, *Learn, Earn & Return: My Life as a Computer Pioneer*, captures the essence of his belief in education and giving back," says Susan. "Education is not limited to the four walls of traditional school settings and making learning possible in a variety of settings with a variety of modalities is a priority for our family. My family is proud to support CHM's Learning Lab and the important work of the Computer History Museum in providing access and opportunity for every learner to think critically about how technology is changing the way we work, live, and play." ○

Harlan Anderson passed away in January 2019. Due to his generosity, his legacy will live on at CHM's Learning Lab.

LIFETIME GIVING SOCIETY

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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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Detail from a recent donation of software development records for the Apollo Guidance Computer, 1962–1963. **Learn more on page 58.**

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FILE GENERATION AGC   D LICKLY 0000 02-14-62
CALCULATION OF CONTROL EQUATIONS. RANGE AND VELOCITY
 - - - - - - - - - - - - - -   - - - - - - - - - -


V =V +P                        150
 R  R  G

D=D+P
     H

     2
L  =V /R - G                       VERTICAL ACCEL NEE
 EQ

L   =LID D                         MAXIMUM ALLOWABLE

 MAX

     -  -
PSI= UL.R /R
         T  T

              -  -  -
THT=-ARCSIN((R *UL).R/R R)
              T        T

  -  -
X=R .R
   T

IF X NEG, THT=PI-THT

GO TO (TAG),170,171,172,173,   169 MODE SELECT.

  174,175,176,177

IF K ZERO, GO TO 180           171 INITIAL MODE,OPEN
    A

IF D/G -K  NEG, GO TO 180
      S  A
```

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