Timelines provides perspectives on HCI history, glancing back at a road that sometimes took unexpected branches and turns. History is not a dry list of events; it is about points of view and differing interpretations.

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Two Women Who Pioneered User-Centered Design

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Histories of HCI emphasize Vannevar Bush and the engineers and scientists who in the 1960s envisioned what computers would make possible: J.C.R. Licklider, Douglas Engelbart, Ted Nelson, Alan Kay, and Nicholas Negroponte. Their words and the prototypes of Engelbart and Ivan Sutherland have inspired countless researchers. In two conversations, Don Chaffin and Judy Olson suggested the field would benefit from a closer examination of the work of Lillian Gilbreth and Grace Hopper, whose relationships to HCI had been overlooked. They were right.

Lillian Gilbreth, 1878–1972
First woman inducted into the National Academy of Engineering

In 1915, Lillian Gilbreth received the first Ph.D. in industrial psychology. Arguably the founder of modern human factors, she brought human psychology to the emerging field of scientific management. Gilbreth received 23 honorary degrees and many awards. Although her work preceded computer use, Gilbreth's range of user-centered methods and choice of topics align with maturing 21st-century HCI.

Gilbreth was born Lillie Moller [1] in Oakland, California, the oldest of nine children of a wealthy builder's supply merchant who feared that educated women would become schoolteachers instead of marrying rich men. At age nine she attended first grade. She caught up and overcame her father's opposition to women's education, commuting by streetcar to UC Berkeley. Majoring in English literature with enough education courses to qualify for a teaching certificate, she was in 1900 Berkeley's first female commencement speaker. Gilbreth was excluded from Phi Beta Kappa; she recalled the policy being that "when it came to finding a good job, men needed the help of this honor more than women did." She went to Columbia to study literature, but the professor she had hoped to work with did not allow women to attend his lectures. Instead, she studied briefly with Edward Thorndike, an influential experimental psychologist with whom she remained in touch for four decades. Thorndike espoused careful quantitative measurement and two principles that Gilbreth absorbed: Individuals are shaped by their environments and differ in their satisfactions.

Gilbreth became ill during her studies in New York. Hearing this, her father forced her to return to California and Berkeley, where she earned a master's in English literature and completed a Ph.D. dissertation that was published serially in a journal in 1912 and 1913 and as an influential book, *The Psychology of Management*, in 1914. The publisher insisted that no publicity mention the gender of "L.M. Gilbreth." Her committee had approved her conducting research on the East Coast but insisted in 1911 that she reside on

campus to be awarded her Ph.D. This was not possible, as by then she had five children with Frank Gilbreth, a bricklayer turned building contractor enthusiastic about Frederic Taylor's scientific management concept. At Lillian's urging, Frank had left his business and the two were conducting research, teaching, and consulting on scientific management for firms in Europe and North America. Lillian Gilbreth wrote and in 1915 successfully defended a second Ph.D. dissertation, "Some Aspects of Eliminating Waste in Teaching," at Brown University. By then, seven of their 12 children had arrived.

During this period, she also researched and wrote books based on their work titled *Bricklaying System, Concrete System, Field System,* and *Motion Studies*, listing only Frank as author. The titles seem consistent with Taylorism [2], the pioneering conceptualization of a scientific approach to measuring work. But the Gilbreths split acrimoniously with the wealthy, autocratic, and jealous Taylor, who focused solely on measuring time and viewed workers as dimwitted, in need of rigid control, and motivated solely by money. The Gilbreths added the study of motion as a step in optimizing work practices, and recognized the complexity of the relationship between motivation and the desirability of reward. They explored training, stress, and fatigue. Even when it produced higher wages, Taylorism was often resisted by workers; the Gilbreths fared better. Their respect for workers anticipated sociotechnical and participatory design. One office boy, an Italian immigrant, wrote of the Gilbreths, "The workmen selected [to be observed and filmed during work-process optimization projects] were always considered not merely as workers but investigators, having respect for their knowledge of their own work and utilizing their experience" [3].

The couple is best known through a book written by two of their children and a 1950 movie of the same name, *Cheaper by the Dozen*. They emphasized Frank's role before he died in 1924, leaving Lillian a single parent of 11 surviving children aged 2 to 18. Some consulting clients abandoned Lillian on Frank's death, but she soon established a strong reputation. She saw all of her children through college while maintaining an unbroken record of singular accomplishment. She worked for a wide range of firms and published extensively.

The range of Lillian's work defies easy summarization. Historian Jane Lancaster's impressive biography, *Making Time*, describes a person with extraordinary powers of observation and analysis and an unparalleled ability to translate results into action by working hard and efficiently, networking strategically, and collaborating effectively. She innovated in redesigning work practices from bricklaying to surgery and in product design, as with a futuristic desk for IBM's 1933 Chicago World's Fair exhibit. Most significantly, she broke new ground in two major areas: women's work and designing for disabilities.

A 1998 thesis, "Lillian Moller Gilbreth's Extensions of Scientific Management into Women's Work: 1924–1935," captures the first of these. Her basic research on menstruation and fatigue concluded that women could continue working without difficulty. Her one foray into market research, in the 1920s, was on sanitary napkins for Johnson & Johnson. She defined work practices to help nurses avoid injury and to aid typists, cashiers, saleswomen, sandwich makers, and others in working more efficiently. Often she first filmed and talked with especially efficient workers. She worked for months at a Macy's sales counter to understand the nature of the work and sources of fatigue. She wrote, "When you go into your man-designed kitchen … you have a simple enough problem in the elimination of unnecessary fatigue in the household…. If those who supply the soap, the water, the sinks, the dishes, etc. actually washed some dishes, we would have much better equipment in a short time." She developed the kitchen "work triangle" used today, along with specific devices that came into wide use, such as refrigerator door shelves and foot-pedal-operated trash containers [4].

World War I casualties galvanized a focus on designing practices and training to enable the handicapped to work. Gilbreth continued this work and extended it to the civilian handicapped, designing kitchens for disabled female homemakers. Of one, she noted emphatically that "there wasn't a single thing in it which wouldn't be equally good for a person who had nothing in the world the matter with her except [being] overweight." She examined the abilities of older workers and opposed age discrimination. Noting that about 85 percent of purchasing was by women, she explored approaches to increasing customer satisfaction. Her engagement over time is not unlike the evolving focus of HCI as computer use moved beyond technical domains.

Gilbreth served five U.S. presidents in significant roles. Although

tangential to user-centered design, as it was with Vannevar Bush and J.C.R. Licklider, her service underlines her prominence, as does her being featured posthumously on a U.S. postage stamp. In 1930, Gilbreth was appointed to the U.S. Emergency Committee for Unemployment. She initiated a program that mobilized almost three million women to collect unemployment data, previously not measured, and to create new jobs. She led the temporarily successful opposition to the proposal that married working women should be fired; the committee responded, "[We] see no way in which the government can discriminate against married women now employed.... This does not commend itself to us as sound from a business point of view or desirable from a social point of view." After a year, though, the government began firing women whose husbands were employed. When Hoover did not support the committee's recommendations, she resigned. Other service is shown in Table 1.

Academic appointments came late in her life. The Gilbreths ran informal free summer schools on scientific management in the early 1920s. Following Frank's death, to supplement contract work as a means of support, Lillian ran a formal course from her home with laboratory projects and field trips to private companies. Frank had lectured annually at Purdue. When he died, Lillian was invited, and in 1935 at age 57 she became Purdue's first female engineering professor. She was soon a full professor with appointments in three departments, also advising the dean on careers for women (with Amelia Earhart, who said, "The most rewarding part of working at Purdue was my connection with Lillian Gilbreth"). She earned honorary doctorates and engineering awards not previously given to a woman. MIT appointed her to a position in 1964, when she was 86. In 1965, she was belatedly elected to the National Academy of Engineering. She retired in 1968, when she was 90.

In conclusion, Lillian Gilbreth brought psychology to the rigorous study of how technology can better support work. Although she did not work on computers, she pioneered highly relevant methods for human-technology interaction in a career with a trajectory resembling that of HCI as it slowly builds out efforts to support the disabled, the elderly, and occupations traditionally held by women.

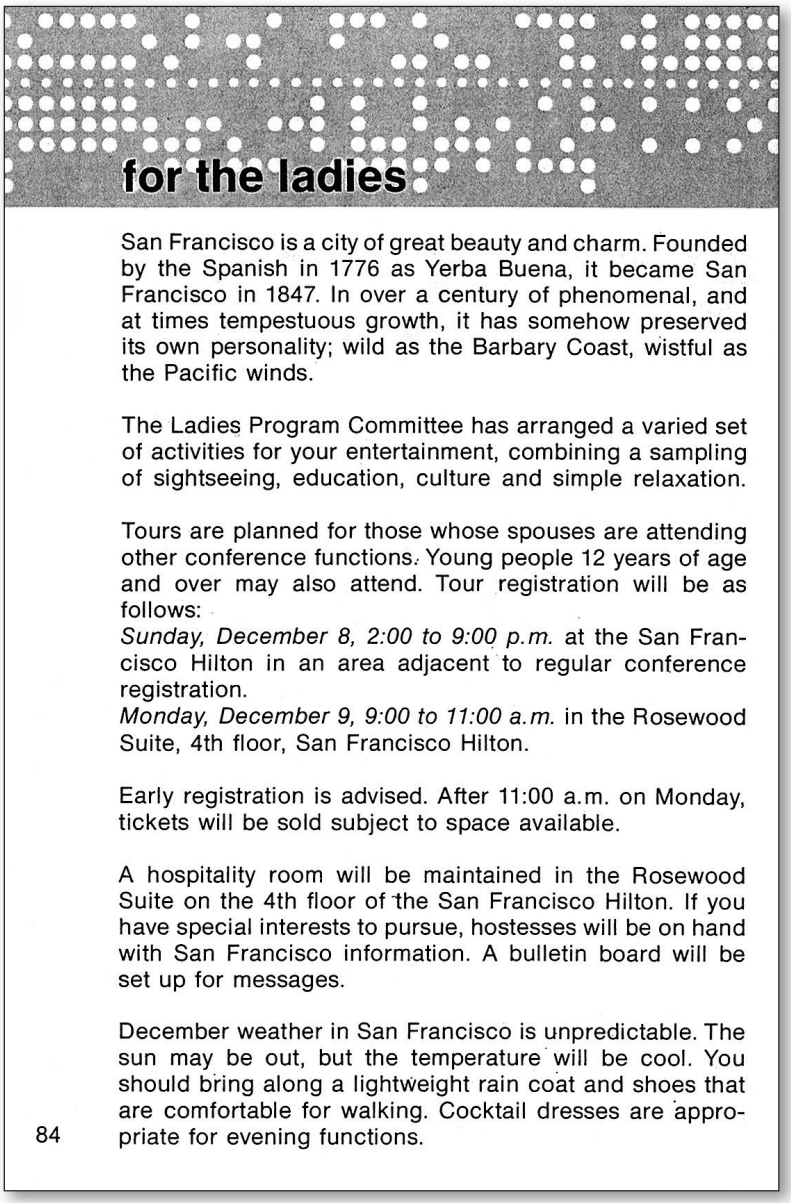
Grace Hopper, 1906–1992

I had a running compiler and nobody would touch it. They told me computers could only do arithmetic.
—Grace Hopper

Grace Hopper is familiar primarily through the annual Women in Computer Science conference named for her. In an unscientific gender-balanced survey, we asked two established HCI researchers and two HCI interns, "What is Grace Hopper famous for?" Both women had attended the Grace Hopper conference. Both interns said, "The bug!" Hopper described the placement of a moth that had crashed a system in a log, popularizing the term *bug* for the origin of a software failure. Both men said she had done something "important in computer science." The female intern said Hopper worked on computers "for the Navy or Army." The prize went to the female researcher, who knew

1920s	Department of Labor, Women's Bureau
1930s	President's Emergency Committee for Employment
1940s	War Manpower Commission
1940s	Office of War Information
1940s	Chemical Warfare Board
1950s	Civil Defense Advisory Council
1940s–1950s	Advisor to Women's Army and Navy Corps (WACS and WAVES, then Defense Advisory Committee on Women in the Services)
1960s	President's Committee on the Employment of the Handicapped

► Table 1. Lillian Gilbreth's government service.



for the ladies

San Francisco is a city of great beauty and charm. Founded by the Spanish in 1776 as Yerba Buena, it became San Francisco in 1847. In over a century of phenomenal, and at times tempestuous growth, it has somehow preserved its own personality; wild as the Barbary Coast, wistful as the Pacific winds.

The Ladies Program Committee has arranged a varied set of activities for your entertainment, combining a sampling of sightseeing, education, culture and simple relaxation.

Tours are planned for those whose spouses are attending other conference functions. Young people 12 years of age and over may also attend. Tour registration will be as follows:
Sunday, December 8, 2:00 to 9:00 p.m. at the San Francisco Hilton in an area adjacent to regular conference registration.
Monday, December 9, 9:00 to 11:00 a.m. in the Rosewood Suite, 4th floor, San Francisco Hilton.

Early registration is advised. After 11:00 a.m. on Monday, tickets will be sold subject to space available.

A hospitality room will be maintained in the Rosewood Suite on the 4th floor of the San Francisco Hilton. If you have special interests to pursue, hostesses will be on hand with San Francisco information. A bulletin board will be set up for messages.

December weather in San Francisco is unpredictable. The sun may be out, but the temperature will be cool. You should bring along a lightweight rain coat and shoes that are comfortable for walking. Cocktail dresses are appropriate for evening functions.

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Hopper had written the first compiler. None of these HCI professionals said, "Grace Hopper was the first HCI visionary." But she was. Reading her papers, it is clear that she pioneered user-centered design.

Grace Murray graduated from the Hartridge School for Girls in 1924, within days of Lillian Gilbreth being widowed 20 miles away. She attended Vassar and at Yale acquired a master's, a Ph.D. in mathematics, and a husband, Vincent Hopper. She began teaching at Vassar in 1931 and in 1943 left to join the Naval Reserve. Lieutenant Hopper was assigned to the Navy's computation project at Harvard. That set her direction for life: She turned down a full professorship at Vassar to continue working with computers in the Harvard Computation Lab, at Eckert-Mauchly/Remington Rand, in the U.S. Navy, and at Digital Equipment Corporation [5].

In the 1940s and 1950s, computers were not used interactively. Programs ran uninterrupted from start to finish, computing missile trajectories, nuclear fission processes, and eventually some business processes. Programs were written, mostly by mathematicians and engineers, in machine code—addresses, registers, and operations represented by sequences of 0s and 1s—or assembly language, with simple mnemonics converted into machine code. Such programming was difficult and the programs were hard to debug, maintain, and port to other computers.

Grace Hopper saw that computer processing could remove this arduous interface and "free mathematicians to do mathematics." Thirty years later, this goal—freeing computer users to focus on their tasks—was fundamental to the emerging field of human-computer

interaction. Hopper's 1952 program to "compile" a higher-level language into machine code—the first compiler—enabled mathematicians to write programs far more quickly. Acceptance of the concept was not immediate, but Hopper and others worked to make compilation and the resulting programs faster and more efficient.

To benefit mathematicians and engineers, Hopper designed a programming language, MATHMATIC, that incorporated arithmetic terms. As business computing slowly grew in the late 1950s, Hopper developed FLOW-MATIC, based on English words rather than abstract commands. She consulted users and determined that abbreviations would not work: Within different divisions of the same company, abbreviation use was inconsistent. She demonstrated the easy substitution of French or German words for English terms, but this early localization effort was stopped because her management felt "it was completely self-evident that an American computer built in Pennsylvania couldn't possibly be programmed in French or German."

A major effort to produce a common programming language for business relied on Hopper and FLOW-MATIC. Some computer scientists on the committee argued for abstract terms, which have advantages in mathematics and engineering, but business users overwhelmingly preferred programs with transparent English commands. The result, COBOL, became the most widely used language following the arrival of mainframes in the mid-1960s.

Computer scientists do not always value HCI and did not always value COBOL or Hopper's contributions. They preferred less transparent but more flexible programming languages such as FORTRAN or LISP. Nevertheless, Hopper was a major influence in academic computer science, especially within ACM. For example, she led the first ACM nomenclature standardization effort, replacing commonly used "magic brain" terminology such as *thinking* and *memory* with terms such as *processing* and *storage*.

The Navy was a base for Hopper's broad range of collaborative activities. She served for 25 years, retiring three times. She was asked to return, exempted from the mandatory retirement age by special approval of the president. When she retired for good in 1986, Rear Admiral Hopper was the oldest active-duty commissioned officer, at almost 80 years old. She is celebrated as an influential computer scientist; her pioneering role in making computation accessible to less technical users is not stressed. Most HCI histories overlook her anticipation of our core vision.

HCI and Gender

Here we have honored the accomplishments of two pioneers whose visions preceded transistors and the dramatic possibilities that semiconductors inspired. Despite our progress in overcoming past discrimination, their major advances in exploring and addressing user needs are not widely recognized.

CHI has always advocated gender-neutral terminology and practice. Our partners in human factors and management information systems were slower in coming around. Despite their longevity, neither pioneer lived to see the *International Journal of Man-Machine Studies,* founded in 1969, become the *International Journal of Human-Computer Studies* in 1994. Nevertheless, to see how far we have come, consider the context of what were arguably the two seminal events in human-computer interaction.

Vannevar Bush and the Memex. It was 1945. The Second World War was over and soldiers were returning. The U.S. government launched a campaign to convince the women who had joined the workforce in large numbers to turn their jobs over to men. Many who resisted were laid off or forced into lower-paying jobs.

Vannevar Bush was an MIT professor and administrator, an advisor to President Roosevelt, and an architect of the National Science Foundation. In 1945, he published two essays in *The Atlantic Monthly*, "As We May Think" and "The Builders." The first described a hypothetical computer-like machine, the Memex. This essay directly inspired Douglas Engelbart, Ted Nelson, and other computer scientists. It is still widely read and quoted.

The Memex was to include vast stores of microfilm moved mechanically and read by ingenious optical devices. Bush envisioned a Web-like multimedia associative memory. "Picture a future investigator in his laboratory. His hands are free, and he is not anchored.... As he moves about and observes, he photographs and comments. Time is automatically recorded to tie the two records together.... As he ponders over his notes in the evening, he again talks his comments into the record.... When the user is building a trail, he names it, inserts the name in his code book, and taps it out on his keyboard."

Bush described how such a machine could be used by a wide

Excerpt from Vannevar Bush's "The Builders"

For those interested in more of Vannevar Bush's take on how science progresses, Bush depicted scientists as if they were building an imposing edifice by quarrying one block at a time:

"[T]he workers sometimes proceed in erratic ways. There are those who are quite content, given a few tools, to dig away unearthing odd blocks, piling them up in the view of fellow workers, and apparently not caring whether they fit anywhere or not. Unfortunately there are also those who watch carefully until some industrious group digs out a particularly ornamental block; whereupon they fit it in place with much gusto, and bow to the crowd. Some groups do not dig at all, but spend all their time arguing as to the exact arrangement of a cornice or an abutment. Some spend all their days trying to pull down a block or two that a rival has put in place. Some, indeed, neither dig nor argue, but go along with crowd, scratch here and there, and enjoy the scenery. Some sit by and give advice, and some just sit.

"On the other hand there are those rare men of vision who can grasp well in advance just the block that is needed for rapid advance on a section of the edifice to be possible, who can tell by some subtle sense where it will be found, and who have an uncanny skill in cleaning away dross and bringing it surely into the light. These are the master workmen. For each of them there can well be many of lesser stature who chip and delve, industriously, but with little grasp of what it is all about, and who nevertheless make the great steps possible."

range of professionals: patent attorneys and other lawyers accessing issued patents or legal cases, chemists consulting the literature, historians accessing records of different epochs, salesmen checking customer records, mathematicians doing low-level arithmetic, scientists accessing data for analysis.

It was inspiring. It also included 142 male pronouns—and two female pronouns in a description of how a typist with electrodes on or in her head might be able to type without using her fingers.

Bush's second 1945 *Atlantic* essay, reprinted from *Technology Review,* developed a clever metaphor of scientists and engineers quarrying stone for a building. After describing different activities that help or hinder progress (see sidebar), he introduces "those men of rare vision."

Bush saw a place for others to help his men of vision: "There are those who bring them food during the labors, and cooling drink when the days are warm, who sing to them, and place flowers…"

Bush inspired many men to become computer engineers and computer scientists. How many women his words inspired to pursue careers in these fields is open to question.

Douglas Engelbart and the Mother of All Demos. At the 1968 Fall Joint Computer Conference in San Francisco, Engelbart gave a truly phenomenal demonstration of the future of computing [6], introducing many features that came into widespread use over the next three decades. Engelbart was not responsible for the printed FJCC program. A page titled "For the Ladies" lists tours arranged by the Ladies Program Committee "combining a sampling of sightseeing, education, culture, and simple relaxation" (see page 18). It concluded by noting, "Cocktail dresses are appropriate for evening functions."

By 1973, change was in the air. The first bestselling HCI book, James Martin's *Design of Man-Computer Dialogues*, begins, "I am informed that the Women's Liberation Movement will object to the title of this book." Well, awareness is an important step, and no one said elemental decency would come easily.

Lillian Gilbreth and Grace Hopper had remarkable, creative, influential, and long careers, contributing deep insights, new methods, and practical applications. Their contributions are not wholly unrecognized, but they deserve much more credit in the fields of user-centered design and human-computer interaction. Gilbreth and Hopper were subject to discrimination because they were women and because they pioneered the merger of psychological considerations and engineering, encountering the ambivalence toward HCI expressed by many computer engineers and scientists. There remains work to do.

Postscript

This concludes the Timelines series: 37 essays by 27 authors over eight years. The diverse perspectives and topics could be starting points for future historians of human-computer interaction, to whom today will be as distant as the era of paper tape and punch cards is now.

Acknowledgments

Thanks to Judy Olson and Don Chaffin for directing us to Gilbreth and Hopper, to Richard Anderson for calling our attention to the announcement of the 1968 Fall Joint Computer Conference, and to Jane Lancaster for her wonderful book and for confirming Gilbreth's MIT connection in the 1980s.

ENDNOTES:

1. Lillie was a family name. When at Berkeley, Gilbreth decided Lillian was more dignified.
2. http://en.wikipedia.org/wiki/Frederick_Winslow_Taylor
3. Lancaster, J. *Making Time: Lillian Moller Gilbreth—A Life Beyond "Cheaper by the Dozen."* Northeastern University Press, 2004, 136.
4. The article "Are You Sure Your Software Is Gender-Neutral?" in this issue addresses inadvertent gender bias in software design.
5. Beyer, K.W. *Grace Hopper and the Invention of the Information Age.* MIT Press, 2009.
6. http://www.youtube.com/watch?v=yJDv-zdhzMY

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DOI: 10.1145/2530538