# ˙Introduction˙
# A MOVING TARGET: THE EVOLUTION OF HCI

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# PREAMBLE: HISTORY IN A TIME
## OF RAPID OBSOLESCENCE

"What is a typewriter?" my six-year-old daughter asked.
I hesitated. "Well, it's like a computer," I began.

### Why Study the History of Human-Computer Interaction?

A paper widely read 20 years ago concluded with the advice to design a word processor by analogy to something familiar to everyone: a typewriter. Even then, one of my Danish students questioned this reading assignment, noting that "the typewriter is a species on its last legs." For most of the computing era, interaction involved 80-column punch cards, paper tape, line editors, 1920-character displays, 1-megabye diskettes, and other extinct species. Are the interaction issues of those times relevant today? No.

Of course, aspects of the human side of human-computer interaction (HCI) change more slowly if at all. Much of what was learned about our perceptual, cognitive, social, and emotional processes when we interacted with older technologies applies to our interaction with emerging technologies. Aspects of how we organize and retrieve information persist, even as the specific technologies that we use change. Other chapters of the Handbook lay out relevant knowledge of human psychology; how and when that came to be learned is not the focus here.

Despite these caveats, the rapid pace of change strengthens the case for understanding the field's history:

1. Several disciplines have engaged in HCI research and application, but few people are exposed to more than one. By seeing how others evolved, we can identify possible benefits in expanding our focus, and obstacles to doing so.
2. Celebrating the accomplishments of past visionaries and innovators is part of building a community and inspiring future contributors, even when some past achievements are difficult to appreciate today.
3. Some visions and prototypes were quickly converted to widespread application, others took decades, and some remain unrealized. By understanding the reasons for different outcomes, we might assess today's visions more realistically.
4. Crystal balls are notoriously unreliable, but anyone planning or managing a career in a rapidly-changing field must consider the future. Our best chance to anticipate change is to find trajectories that extend from the past through the present. One thing is certain: The future will not resemble the present.

This account does not emphasize engineering "firsts." It focuses on technologies and practices as they became widely used, reflected in the spread of systems and applications. This was often accompanied by the formation of new research fields and changes in existing disciplines, marked by the creation and evolution of professional associations and publications. More a social history than a conceptual history, this survey points to trends and trajectories that you might download into your crystal balls.

A historical account is a perspective. It emphasizes some things while de-emphasizing or omitting others. A history can be wrong in details, but is never right in any final sense. Your questions and your interests will determine whether or not a perspective is useful to you.

A blueprint for intellectual histories of HCI was established by Ron Baecker in the opening chapters of the 1987 and 1995 editions of *Readings in Human-Computer Interaction.* It was followed in Richard Pew's chapter in the 2003 version of this Handbook. Brian Shackel's (1997) account of European contributions, and specialized essays by Brad Myers (1998) on HCI engineering history and Alan Blackwell (2006) on the history of metaphor in design, provide further insights and references. Perlman et al. (1995) is a compendium of early HCI papers that appeared in the Human Factors literature. HCI research within Management Information Systems is covered in Banker and Kaufmann (2004) and Zhang et al. (2009). Rayward (1983; 1998) and Burke (1994; 2007) review the pre-digital history of Information Science; Burke (1998) is a focused study of an early digital effort in this field.

Recent years have seen a wave of popular books covering the history of personal computing (e.g., Hiltzik, 1999; Bardini, 2000; Hertzfeld, 2005; Markoff, 2005; Moggridge, 2007). This chapter extends my contribution to the previous handbook, drawing also on *Timelines* columns that have appeared in *ACM Interactions* since March 2006.

Few of the writers listed above are trained historians. Many of us lived through much of the computing era as participants and witnesses, yielding rich insights and questionable objectivity. This account draws on extensive literature and hundreds of formal interviews and discussions, but everyone has biases. Personal experiences that illustrate points can enliven an account, conveying human consequences of changes that otherwise appear abstract or distant. Some readers enjoy anecdotes, others find them irritating. I try to satisfy both groups by including personal examples in a short Appendix, akin to "de-

leted scenes" on a DVD.

Recent years have also seen the appearance of high-quality, freely accessed digital reproductions of some early works. My references include URLs for several such works. They do not always preserve the original pagination, but quoted passages can be found by using a search tool. Finally, all prices and costs have been converted to 2010 U.S. dollars.

## Definitions: HCI, CHI, HF&E, IT, IS, LIS

The most significant term, HCI (human-computer interaction), is defined very broadly here to cover major threads of research in four disciplines: Human Factors, Information Systems, Computer Science, and Library & Information Science. The relevant literatures are difficult to explore because of differences in how many simple terms are used. This is covered later in the chapter. Here I explain how several key disciplinary labels will be used. CHI (Computer-Human Interaction) has a narrower focus, associated mainly with Computer Science, the Association for Computing Machinery Special Interest Group (ACM SIGCHI), and the latter's annual CHI conference. I use human factors (HF), ergonomics (E), and HF&E interchangeably—some writers define ergonomics more narrowly around hardware. The Human Factors Society (HFS) became the Human Factors and Ergonomics Society (HFES) in 1992. IS (information systems) refers to the management discipline that has also been labeled data processing (DP) and management information systems (MIS). I follow common parlance in referring to organizational information systems specialists as IT professionals or IT pros. With IS taken, I do not abbreviate Information Science, but LIS (library and information science) represents an old field with a new digital incarnation that includes some important HCI research. Increasingly this discipline goes by simply 'Information,' as in the rapidly appearing Schools of Information.

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# HUMAN-TOOL INTERACTION AND INFORMATION PROCESSING AT THE DAWN OF COMPUTING

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In the century prior to the first digital computers, advances in technology gave rise to two fields of research that later contributed to human-computer interaction. One focused on making the human use of tools more efficient, the other on ways to represent and distribute information more effectively.

## Origins of Human Factors

Frederick Taylor (1911) employed technologies and methods developed in the late 19th century—photography, moving pictures, and statistical analysis—to improve work practices by reducing performance time. Time-and-motion studies were applied to assembly-line manufacturing and other manual tasks. Despite the uneasiness with "Taylorism" reflected in Charlie Chaplin's popular satire "Modern Times," scientists and engineers strove to boost efficiency and productivity.

Lillian Gilbreth (1914) and her husband Frank became the first engineers to combine psychology with scientific management. Focusing more holistically than Taylor on efficiency and worker experience, Lillian Gilbreth is regarded by some as the first in the field that became modern Human Factors. Her PhD was the first degree awarded in industrial psychology. She went on to advise five U.S. presidents and was the first woman inducted into the National Academy of Engineering.

The World Wars accelerated efforts to match people to jobs, train them, and design equipment that could be more easily mastered. Engineering psychology was born during World War II after simple flaws in the design of aircraft controls (Roscoe, 1997) and escape hatches (Dyson, 1979) led to aircraft losses and thousands of casualties. Two legacies of World War II were respect for the potential of computing, based on its use in code-breaking, and an enduring interest in behavioral requirements for design.

During the war, aviation engineers, psychologists, and physicians formed the Aeromedical Engineering Association. After the war, the terms 'human engineering,' 'human factors,' and 'ergonomics' came into use, the latter primarily in Europe. For more on this history, see Roscoe (1997), Meister (1999), and HFES (2010).

Early tool use, whether by assembly-line workers or pilots, was not discretionary. If training was necessary, people were trained. One research goal was to reduce training time, but more important was to increase the speed and reliability of skilled performance.

## Origins of the Focus on Information

H. G. Wells, known as a science fiction writer, campaigned for decades to improve society through information dissemination. In 1905 he outlined a system that might be built using another new technology of the era: index cards!

These index cards might conceivably be transparent and so contrived as to give a photographic copy promptly whenever it was needed, and they could have an attachment into which would slip a ticket bearing the name of the locality in which the individual was last reported. A little army of attendants would be at work on this index day and night… An incessant stream of information would come, of births, of deaths, of arrivals at inns, of applications to post-offices for letters, of tickets taken for long journeys, of criminal convictions, marriages, applications for public doles and the like. A filter of offices would sort the stream, and all day and all night for ever a swarm of clerks would go to and fro correcting this central register, and photographing copies of its entries for transmission to the subordinate local stations, in response to their inquiries…

Would such a human-powered "Web 2.0" be a tool for social control or public information access? The image evokes the potential, and also the challenges, of the information era that is taking shape around us a century later.

In the late 19th century, technologies and practices for compressing, distributing, and organizing information bloomed. Index cards, folders, and filing cabinets—models for icons on computer displays much later—were important inventions that influenced the management of information and organizations in the early 20th century (Yates, 1989). Typewriters and carbon paper facilitated information dissemination, as did the mimeograph machine, patented by Thomas Edison. Hollerith cards and electromechanical tabulation, celebrated steps toward computing, were heavily used to process information in industry.

Photography was used to record information as well as behavior. For almost a century, microfilm was the most efficient way to compress, duplicate, and disseminate large amounts of information. Paul Otlet, Vannevar Bush, and other microfilm advocates played a major role in shaping the future of information technology.

As the cost of paper, printing, and transportation dropped in the late 19th and early 20th centuries, information dissemination and the profession of librarianship grew explosively. Library Associations formed. The Dewey Decimal and Library of Congress classification systems were developed. Thousands of relatively poorly-funded public libraries sprang up to serve local demand in the U.S. In Europe, government-funded libraries were established to serve scientists and other specialized elites. This difference led to different approaches to technology development on each side of the Atlantic.

In the United States, library management and the training of thousands of librarians took precedence over technology development and the needs of specialists in medicine, science, and the humanities. Public libraries adopted the simple but inflexible Dewey Decimal system. The pragmatic focus of libraries and emerging library schools meant that research into technology was in the province of industry, research into indexing, cataloging, and information retrieval, variously referred to as Bibliography, Documentation, and Documentalism.

In contrast, the well-funded European special libraries elicited sophisticated reader demands and pressure for libraries to share resources, which promoted interest in technology and information management. The Belgian Paul Otlet obtained Melvyn Dewey's permission to create an extended version of the Dewey Decimal classification system that supported what we would today call hypertext links. Otlet had to agree not to implement his Universal Decimal Classification (UDC) in English for a time, an early example of a legal constraint on technology development, but the UDC is still in use in some places.

In 1926, the Carnegie Foundation dropped a bombshell: It endowed the Graduate Library School (GLS) at the University of Chicago to focus solely on research. For two decades Chicago was the only university granting PhDs in library studies. GLS positioned itself in the humanities and social sciences, with research into the history of publishing, typography, and other topics (Buckland, 1998). *An Introduction to Library Science,* the dominant library research textbook for forty years, was written at Chicago (Butler, 1933). *It did not mention information technology at all.* Human-tool interaction was not part of Library Science, which was shaped by the prestigious GLS program until well into the computer era. Documentalists were concentrated in industry and government agencies.

Burke (2007, p. 15) summarized the early history, with its emphasis on training librarians and other specialists:

Most information professionals…were focusing on providing information to specialists as quickly as possible. The terms used by contemporary specialists appeared to be satisfactory for many indexing tasks and there seemed no need for systems based on comprehensive and intellectually pleasing classification schemes. The goal of creating tools useful to non-specialists was, at best, of secondary importance.

This chapter will emphasize when computer technologies came into what might be called 'non-specialist use.' This early history is significant, however, because the Web and declining digital storage costs have made it evident that everyone will soon be their own information manager, just as we are all now telephone operators. But I am getting ahead of our story. This section concludes with accounts of two individuals who, in different ways, shaped the history of information research and development.

*Paul Otlet and the Mundaneum.* Like his contemporary H.G. Wells, Otlet envisioned a vast network of information. Unlike Wells, Otlet and his collaborators built one. Otlet established a commercial research service around facts he had been cata-

loging on index cards since the late 19th century. In 1919 the Belgian government financed the effort, which moved to a record center called the Mundaneum. By 1934, 15 million index cards and millions of images were organized using the Universal Decimal Classification, with its formula that enabled the linking of items. Curtailed by the Depression and damaged during World War II, the work was largely forgotten. It was not cited by the developers of the metaphorically identical Xerox Notecards, an influential hypertext system of the 1980s.

Technological innovation continued in Europe with the development of mechanical systems of remarkable ingenuity (Buckland, 2009). Features included the use of photoreceptors to detect light passing through holes in index cards positioned to represent different terms, enabling rapid retrieval of items on specific topics. These innovations inspired a well-known American scientist and research manager.

*Vannevar Bush and microfilm machines.* MIT professor Vannevar Bush was one of the most influential scientists in American history. He advised Presidents Franklin Roosevelt and Harry Truman, served as Director of the Office of Scientific Research and Development, and was President of the Carnegie Institute.

Bush is remembered today for *As We May Think*, his 1945 *Atlantic Monthly* essay. It described the MEMEX, a hypothetical microfilm-based electromechanical information processing machine. The MEMEX was to be a personal workstation that enabled a professional to quickly index and retrieve documents or pictures and create hypertext-like associations among them. The essay, excerpted below, inspired computer engineers and computer scientists who made major contributions to human-computer interaction in the 1960s and beyond.

Not so well known is that Bush wrote the core of his essay in the early 1930s. Then, shrouded in secrecy, he spent two decades and unprecedented resources on the design and construction of several machines that comprised a subset of the MEMEX features. None were successful. The details are recounted in Colin Burke's comprehensive 1994 book *Information and secrecy: Vannevar Bush, Ultra, and the other Memex.*

Microfilm—photographic miniaturization—had qualities that attracted Bush, as they had Otlet. Microfilm was light, easily transported, and as easy to duplicate as paper (Xerox photocopiers did not appear until 1959). The cost of handling film was brought down by technology created for the moving picture industry. Barcode-like patterns of small holes could be punched on a film and read very quickly by passing the film between light beams and photoreceptors. Microfilm was a tremendously efficient as a storage medium. Memory based on relays or vacuum tubes would never be competitive, and magnetic memory, when it eventually arrived, was less versatile and far more expensive. It is easy today to overlook the compelling case that existed for basing information systems on microfilm.

Bush's machines failed because he set overly ambitious compression and speed goals, he ignored patent ownership issues, and most relevant to our account, he was unaware of what librarians and documentalists were discovering through decades of work on classification systems. American documentalists were active though not well-funded. In 1937, the American Documentation Institute (ADI) formed, predecessor of today's American Society for Information Science and Technology (ASIST). Had he worked with them, Bush, an electrical engineer by training, might have avoided the fatal assumption that small sets of useful indexing terms would easily be defined and agreed upon. Metadata design is still a research challenge.

At times, Bush considered libraries and the public as potential users, but his machines cost far too much for library patrons to be plausible users. He began with the FBI in mind, focused on military uses of cryptography and information retrieval, and a major project was for the CIA. Despite the classified nature of this work, through his academic and government positions, his writings, the vast resources he commandeered, and the scores of brilliant engineers he enlisted to work on microfilm projects, Bush promoted his vision and exerted influence for two decades, well into the computer era.

Bush's vision emphasized both the associative linking of information sources and discretionary use:

Associative indexing, the basic idea of which is a provision whereby any item may be caused at will to select immediately and automatically another. This is the essential feature of the MEMEX… Any item can be joined into numerous trails… New forms of encyclopedias will appear, ready made with a mesh of associative trails [which a user could extend]…

The lawyer has at his touch the associated opinions and decisions of his whole experience and of the experience of friends and authorities. The patent attorney has on call the millions of issued patents, with familiar trails to every point of his client's interest. The physician, puzzled by a patient's reactions, strikes the trail established in studying an earlier similar case and runs rapidly through analogous case histories, with side references to the classics for the pertinent anatomy and histology. The chemist, struggling with the synthesis of an organic compound, has all the chemical literature before him in his laboratory, with trails following the analogies of compounds and side trails to their physical and chemical behavior.

The historian, with a vast chronological account of a people, parallels it with a skip trail which stops only on the salient items, and can follow at any time contemporary trails which lead him all over civilization at a particular epoch. There is a new profession of trail blazers, those who find delight in the task of establishing useful trails through the enormous mass of the common record. (Bush, 1945.)

Bush knew that the MEMEX was not realistic. None of his many projects included designs for the "essential" associative linking. His inspirational account nicely describes today's hands-on discretionary use of computers by professionals. But that would arrive 50 years in the future, built on technologies then undreamt of. Bush did not support the early use of computers, which were slow, bulky, and expensive. Computers were clearly inferior to microfilm.

# 1945–1955: MANAGING VACUUM TUBES

World War II changed everything. Prior to the war, government funding of research was minimal and primarily managed by the Department of Agriculture. The unprecedented investment in science and technology during the war years revealed that huge sums could be found--*for academic or industrial research that addressed national goals.* Research expectations and strategies would never be the same.

Sophisticated electronic computation machines built before and during World War II were designed for specific purposes, such as solving equations or breaking codes. Each of the extremely expensive cryptographic machines helped win the war was designed to attack a specific encryption device. A new one was needed whenever the enemy changed machines. These limitations spurred interest in general-purpose computational devices. War-time improvements in technologies such as vacuum tubes made them more feasible, and their deployment brought human-computer interaction into the foreground.

When engineers and mathematicians emerged from military and government laboratories (and secret project rooms on university campuses), the public became aware of some breakthroughs. ENIAC, arguably the first general-purpose computer, was begun in secret during the war but announced publicly as a 'giant brain' when it was completed in 1946. (Its first use, for calculations supporting hydrogen bomb development, was not publicized.) Accounts of ENIAC dimensions vary, but it stood eight to ten feet high, occupied about 1800 square feet, and consumed as much energy as a small town. It provided far less computation and memory than today can be acquired for a few dollars, slipped into a pocket, and run on a small battery.

Memory was inordinately expensive. Even the largest computers of the time had little memory, so they were used for computation, not for symbolic representation or information processing. Reducing operator burden was a key HCI focus: replacing or resetting vacuum tubes more quickly, loading stored-program computers from tape rather than by manually attaching cables and setting switches. Following 'knobs and dials' human factors improvements, one computer operator could accomplish work that had previously required a team.

Libraries installed simple microfilm readers to assist in retrieving information as publication of scholarly and popular material soared. Beyond that, library and library school involvement with technology was limited, even as the foundation for Information Science came into place. The war had forged alliances among the documentalists, electrical engineers, and mathematicians interested in communication and information management. Vannevar Bush's collaborators who played roles included Claude Shannon and Warren Weaver, co-authors in 1949 of the seminal work on Information Theory (at that time called Communication Theory). Prominent American documentalist Ralph Shaw joined Bush's efforts. Library schools continued to focus on librarianship, social science and historical research. The GLS orientation still dominated. The split was if anything greater: In the 1930s, the technology-oriented ADI included librarians and support for systems that spanned the humanities and sciences; with the war and continuing after it, ADI's concerns were those of government and 'Big Science.'

## Three Roles in Early Computing

Early computer projects employed people as: (i) managers, (ii) programmers, and (iii) operators. Managers oversaw design, development, and operation. They specified the programs to be written and distributed the output. Scientists and engineers wrote the programs, working with mathematically adept programmers who decomposed a task into components that the computer could manage (for ENIAC, this was a team of six women). A small army of operators was needed. Once written, a program could take days to load by setting switches, dials, and cable connections. Despite innovations that boosted reliability, including operating vacuum tubes at lower than normal power and building in visible indicators of their failure, ENIAC was often stopped to locate and replace failed tubes. Vacuum tubes were reportedly wheeled around in shopping carts.

Eventually, each occupation—computer operation, management and systems analysis, and programming—became a major focus of HCI research, centered respectively in Human Factors, Information Systems, and Computer Science. Computers and our interaction with them evolved, but our research spectrum still reflects aspects of this early division of labor.

*Grace Hopper, Liberating Computer Users.* As computers became more reliable and capable, programming became a central activity. Computer languages, compilers, and constructs such as subroutines facilitated 'programmer-computer interaction.' Grace Hopper was a pioneer in these areas. She described her goal as being to free mathematicians to do mathematics (Hopper, 1952; see also Sammet, 1992). This is echoed in today's usability goal of freeing users to do their work. HCI professionals often argue that they are marginalized by software developers; in much the same way, Hopper's accomplishments have arguably been undervalued by theoretical computer scientists.

Early forecasts that the world would need few computers reflected the limitations of vacuum tubes. Solid-state computers, first available commercially in 1958, changed this. Computers were still used primarily for scientific and engineering tasks, but they were reliable enough not to require a staff of computer engineers. The less computer-savvy operators who oversaw them needed better interfaces. And although computers were too expensive and limited to be widely use, the potential of transistor-based computing was evident. Some researchers envisioned possibilities that were previously unimaginable.

Another major force was the reaction to the Soviet Union's launch of the Sputnik satellite in October, 1957. This was a challenge to the West to invest in science and technology; becoming part of the response was a way to tie a research program to the national interest, which World War II had revealed to be so effective.

## Supporting Operators: The First Systematic HCI Research

> "In the beginning, the computer was so costly that it had to be kept gainfully
> occupied for every second; people were almost slaves to feed it."
> —Brian Shackel (1997, p. 97)

Almost all computer use of this period involved programs and data that were read in from cards or tape. Programs then ran without interruption until they terminated, along the way producing printed, punched, or tape output. This 'batch processing' restricted human-computer interaction to basic operation, programming, and use of the output. Of these, only computer operation, the lowest-paid and least intellectually challenging job, involved hands-on computer use.

Computer operators loaded and unloaded cards and magnetic or paper tapes, set switches, pushed buttons, read lights, loaded and burst printer paper, and put printouts into distribution bins. Operators interacted directly with the system via a teletype: typed commands interleaved with computer responses and status messages were printed on paper that scrolled up one line at a time. Eventually, they yielded to 'glass tty's' (glass teletypes), also called cathode ray tubes (CRTs) and visual display units/terminals (VDUs/VDTs). For many years, these displays also scrolled commands and computer responses one line at a time. A monochrome terminal that could only display alphanumeric characters cost $50,000 in today's dollars: expensive, but a small fraction of the cost of a computer. A large computer might have one or more consoles. Programmers did not use the interactive consoles. Programs were typically written on paper and keypunched onto cards or tape.

Improving the design of buttons, switches, and displays was a natural extension of human factors. Experts in human factors and ergonomics authored the first HCI papers. In 1959, British researcher Brian Shackel published "Ergonomics for a Computer," followed in 1962 by "Ergonomics in the Design of a Large Digital Computer Console." These described console redesign for analog and digital computers called the EMIac and EMIdec 2400. Shackel (1997) described the latter as the largest computer at that time.

In the United States, American aviation psychologists created the Human Engineering Society in 1956, focused on skilled performance: improving efficiency, reducing errors, and training. The next year it adopted the more elegant title, Human Factors Society, year and in 1958 initiated the journal *Human Factors.* Sid Smith's (1963) "Man–Computer Information Transfer" marked the start of his long career in the human factors of computing.

## Visions and Demonstrations

As transistors replaced vacuum tubes, a wave of imaginative writing, conceptual innovation, and prototype-building swept through the research community. Some of the language is dated, notably the use of male generics, but many of the key concepts resonate today.

*J.C.R. Licklider at BBN and ARPA.* Licklider, a psychologist, played a dual role. He wrote influential essays and backed important research projects, as a manager at Bolt Beranek and Newman (BBN) from 1957-1962 and from 1962-1964 as director of the Information Processing Techniques Office (IPTO) of the Department of Defense Advanced Research Projects Agency (called ARPA and DARPA at different times).

BBN employed dozens of influential researchers on computer-related projects funded by the government, including John Seely Brown, Richard Pew, and many MIT faculty members, such as John McCarthy, Marvin Minsky, and Licklider himself. IPTO funding was crucial in creating computer science departments and establishing artificial intelligence as a field in the 1960s. It is best known for a Licklider project that created the forerunner of the Internet called the ARPANET until 1985.

In 1960, Licklider outlined a vision he called *man-machine symbiosis*: "There are many man-machine systems. At present, however, there are no man-computer symbioses—answers are needed." The computer was "a fast information-retrieval and data-processing machine" destined to play a larger role: "One of the main aims of man-computer symbiosis is to bring the

computing machine effectively into the formulative parts of technical problems." (pp. 4-5.)

This would require rapid, real-time interaction, which batch systems did not support. In 1962 Licklider and Wes Clark outlined the requirements of a system for "on-line man-computer communication." They identified capabilities that they felt were ripe for development: time-sharing of a computer among many users; electronic input-output surfaces to display and communicate symbolic and pictorial information; interactive, real-time support for programming and information processing; large-scale information storage and retrieval systems; and facilitation of human cooperation. They foresaw that other desirable technologies, such as speech recognition and natural language understanding, would be very difficult to achieve.

In a 1963 memorandum that cleverly tied computing to the emerging post-Sputnik space program, Licklider addressed his colleagues as "the members and affiliates of the Intergalactic Computer Network" and identified many features of a future Internet (Licklider, 1963). His 1965 book *Libraries of the Future* expanded this vision. Licklider's role in advancing computer science and HCI is detailed in Waldrop (2001).

*John McCarthy, Christopher Strachey, Wesley Clark.* McCarthy and Strachey worked out details of time-sharing, a crucial element of interactive computing (Fano & Corbato, 1966). Apart from a small number of researchers with access to computers built with spare-no-expense military funding, computer use was too expensive to support interactively that exclusive access. Time-sharing allowed several (and later dozens) of simultaneous users working at terminals. Languages were developed to facilitate the control and programming of time-sharing systems (e.g., JOSS in 1964).

Clark was instrumental in building the TX-0 and TX-2 at MIT's Lincoln Labs to demonstrate time-sharing and other innovative concepts. These machines, which cost on the order of $10 million, helped establish the Boston area as a center for computer research. The TX-2 was the most powerful and capable computer in the world at the time. It was less powerful than a smartphone is today. Clark and Ivan Sutherland discussed this era in a CHI'05 panel, accessible online (ePresence, 2006).

*Ivan Sutherland and Computer Graphics.* Sutherland's 1963 Ph.D. thesis could be the most influential document in the history of HCI. His Sketchpad system, built on the TX-2 to make computers "more approachable," launched computer graphics, which would have a decisive impact on HCI twenty years later. A nice version restored by Alan Blackwell and Kerry Rodden is at http://www.cl.cam.ac.uk/TechReports/UCAM-CL-TR-574.pdf.

Sutherland demonstrated iconic representations of software constraints, object-oriented programming concepts, and copying, moving, and deleting of hierarchically organized objects. He explored novel interaction techniques, such as picture construction using a light pen. He facilitated visualization by separating the coordinate system used to define a picture from the one used to display it, and demonstrated animated graphics, noting the potential for digitally rendered cartoons 20 years before *Toy Story.* His frank descriptions—when engineers found Sketchpad too limited for computer-assisted design (CAD), he called the trial a "big flop" and indicated why—enabled others to make rapid progress.

In 1964, his Ph.D. behind him, Sutherland succeeded Licklider as the director of IPTO. Among those he funded was Douglas Engelbart at the Stanford Research Institute.

*Douglas Engelbart, Augmenting Human Intellect.* In 1962, Engelbart published "Augmenting human intellect: A conceptual framework." Over the next several years he built systems that made astonishing strides toward realizing this vision. He also supported and inspired engineers and programmers who went on to make major independent contributions.

Echoing Bush and Licklider, Engelbart saw the potential for computers to become congenial tools that people would choose to use interactively:

By 'augmenting human intellect' we mean increasing the capability of a man to approach a complex problem situation, to gain comprehension to suit his particular needs, and to derive solutions to problems… By 'complex situations' we include the professional problems of diplomats, executives, social scientists, life scientists, physical scientists, attorneys, designers… We refer to a way of life in an integrated domain where hunches, cut-and-try, intangibles, and the human 'feel for a situation' usefully co-exist with powerful concepts, streamlined terminology and notation, sophisticated methods, and high-powered electronic aids. (p. 1)

Engelbart used ARPA funding to rapidly develop and integrate an extraordinary set of prototype applications into his NLS system. In doing so, he conceptualized and implemented the foundations of word processing, invented or refined input devices including the mouse and multikey control box, and made use of multi-display environments that integrated text, graphics, and video in windows. These unparalleled advances were demonstrated in a sensational 90-minute live event at the 1968 Fall Joint Computer Conference in San Francisco (http://sloan.stanford.edu/MouseSite/1968Demo.html). The focal point for interactive systems research in the United States was moving from the East Coast to the West Coast.

Engelbart, an engineer, supported human factors testing to improve efficiency and reduce errors in skilled use, with concern for effects of fatigue and stress. Engelbart's systems required training; he felt that people should be willing to tackle a difficult interface if it delivered great power once mastered. Unfortunately, the lack of concern for initial usability was a factor in Engelbart's loss of funding. His demonstration became something of a success disaster: DARPA was impressed and installed NLS, but found it too difficult to use (Bardini, 2000). Years later, the question "Is it more important to optimize for skilled use or initial use?" was widely debated. It still occasionally surfaces in HCI discussions.

*Ted Nelson's Vision of Interconnectedness.* In 1960, Ted Nelson, a graduate student in sociology who coined the term *hypertext,* founded Project Xanadu. The goal was an easily used computer network. In 1965, he published a paper titled "A file structure for the complex, the changing and the indeterminate." Nelson continued to write stirring calls for systems to democratize computing through a highly interconnected, extensible network of digital objects (e.g., Nelson, 1973). Xanadu was never fully realized. Nelson did not consider the early World Wide Web to be an adequate realization of his vision, but lightweight technologies such as weblogs, wikis, collaborative tagging, and search enable many of the activities he envisioned.

Later, Nelson foresaw intellectual property issues arising in digital domains and coined the term 'micropayment' (Nelson, 1996). Although his solutions were again not fully implemented, they drew attention to the matter.


## From Documentation to Information Science

The late 1950s saw the last major investments in microfilm and other pre-digital systems. The most ambitious were military and intelligence systems, including Vannevar Bush's final efforts (Burke, 1994). Documentalists began to see that declining memory costs would enable computation engines to become information processing machines. The conceptual evolution was relatively continuous, but at the institutional level, change could come swiftly. New professions—mathematicians and engineers—engaged in technology development, new initiatives were launched that still bore few ties to contemporary librarianship or the humanities orientation of library schools. A new banner was needed.

Merriam Webster dates 'information science' to 1960. Conferences held at Georgia Institute of Technology in 1961 are credited with shifting the focus from information as a technology to information as an incipient science. In 1963, chemist-turned-documentalist Jason Farradane taught the first Information Science courses at City University, London. The profession of chemistry had long invested in organizing their literature systematically, and another chemist-turned-documentalist, Allen Kent, was at the center of a major Information Science initiative at the University of Pittsburgh (Aspray, 1999). In the early 1960s, Anthony Debons, a psychologist and friend of J.C.R. Licklider, organized a series of NATO-sponsored congresses at Pittsburgh. Guided by Douglas Engelbart, these meetings centered on people and augmenting their activities through technology. In 1964 the Graduate Library School at the University of Pittsburgh became the Graduate School of Library and Information Sciences, and Georgia Tech formed a "School of Information Science," initially with one full-time faculty member.


## Conclusion: Visions, Demos, and Widespread Use

Progress in HCI can be understood in terms of inspiring visions, conceptual advances that enable aspects of the visions to be demonstrated in working prototypes, and the evolution of design and application. The engine, enabling visions to be realized and soon thereafter to be widely deployed, was the relentless hardware advance that produced devices millions of times more powerful than the much more expensive systems designed and used by the pioneers.

At the conceptual level, much of the basic foundation for today's graphical user interfaces was in place by 1965. However, at that time it required individual use of a $10 million custom-built machine. Pew (2003, p. 3) describes the 1960 Digital Equipment Corporation (DEC) PDP-1 as a breakthrough, "truly a computer with which an individual could interact." The PDP-1 came with CRT display, keyboard, light pen, and paper tape reader. It cost about $1 million and had the capacity that a Radio Shack TRS 80 had twenty years later. It required considerable technical and programming support. Even the PDP-1 could only be used by a few fortunate computer-savvy researchers.

Licklider's "man–computer symbiosis," Engelbart's "augmenting human intellect," and Nelson's "conceptual framework for man–machine everything" described a world that did not exist. It was a world in which attorneys, doctors, chemists, and designers chose to become hands-on users of computers. For some time to come, the reality would be that most hands-on users were computer operators engaged in routine, nondiscretionary tasks. As for the visions, 40 years later some of the capabilities are taken for granted, some are just being realized, and others remain elusive.


# 1965–1980: HCI PRIOR TO PERSONAL COMPUTING

Control Data Corporation launched the transistor-based 6000 series computers in 1964. In 1965, commercial computers based on integrated circuits arrived with the IBM System/360. These powerful systems, later called mainframes to distinguish them from minicomputers, brought computing into the business realm. Each of the three roles in computing—operation, management, programming—became a significant profession.

Operators still interacted directly with computers for routine maintenance and operation, and as timesharing spread, hands-on use expanded to include data entry and other repetitive tasks. Managers and systems analysts oversaw hardware

acquisition, software development, operation, and the use of output. They were usually not hands-on, but people who relied on printed output and reports did call themselves 'computer users.'

Apart from those working in research settings, programmers were rarely direct users until late in this period. Many of them flowcharted and wrote programs on paper forms. Keypunch operators then punched the program instructions onto cards. These were sent to computer centers for computer operators to run. Printouts and other output were picked up later. Many programmers would use computers directly when they could, but the cost generally dictated this efficient division of labor.

As noted earlier, my focus is on broad trends. Business computing took off in the mid-1960s, but the 1951 LEO I was probably the first commercial business computer. This interesting venture, which ended as the mainframe era began, is detailed in Wikipedia and numerous books and articles referenced there.


## Human Factors and Ergonomics Embrace Computer Operation

In 1970, Brian Shackel founded the Human Sciences and Advanced Technology (HUSAT) center at Loughborough University in the UK, devoted to ergonomics research that emphasized HCI. Sid Smith and other human factors engineers worked on input and output issues, such as the representation of information on displays (e.g., S.L. Smith, Farquhar & Thomas, 1965) and computer-generated speech (S.L. Smith and Goodwin, 1970). The Computer Systems Technical Group (CSTG) of the Human Factors Society formed in 1972 and soon was the largest technical group in the society.

The general *Human Factors* journal was joined in 1969 by the computer-focused *International Journal of Man-Machine Studies (IJMMS)*. The first widely-read HCI book was James Martin's 1973 *Design of Man-Computer Dialogues*. Martin's comprehensive survey of interfaces for operation and data entry began with an arresting opening chapter that described a world in transition. Extrapolating from declining hardware prices, Martin wrote:

The terminal or console operator, instead of being a peripheral consideration, will become the tail that wags the whole dog. . . . The computer industry will be forced to become increasingly concerned with the usage of people, rather than with the computer's intestines. (pp. 3–4)

In the mid-1970s, U.S. government agencies responsible for agriculture and social security initiated large-scale data processing system projects, described in Pew (2003). Although not successful, these efforts led to methodological innovation in the use of style guides, usability labs, prototyping, and task analysis.

In 1980, three significant HF&E books were published: two on VDT design (Cakir, Hart & Stewart, 1980; Grandjean & Vigliani, 1980) and one general guideline (Damodaran, Simpson & Wilson, 1980). Drafts of German work on VDT standards, made public in 1981, provided an economic incentive to design for human capabilities by threatening to ban noncompliant products. Later the same year, a corresponding ANSI standards group for 'office and text systems' formed.


## Information Systems Addresses the Management of Computing

Companies acquired expensive business computers to address major organizational concerns. Even when the principal concern was simply to appear modern (Greenbaum, 1979), the desire to show benefits from a multi-million dollar investment could chain managers to a computer almost as tightly as the operator and data entry 'slaves.' In addition to being expected to make use of output, they could encounter user resistance to a system.

Beginning in 1967, the journal Management Science published a column titled "Information Systems in Management Science." Early definitions of IS included "an integrated man/machine system for providing information to support the operation, management, and decision-making functions in an organization" and "the effective design, delivery and use of information systems in organizations" (Davis, 1974, & Keen, 1980, quoted in Zhang, Nah & Preece, 2004, p. 147). In 1968, an MIS center and degree program was established at Minnesota, which initiated several influential research streams and in 1977 launched *MIS Quarterly*, the leading journal in the field. The MIS field juxtaposed a focus on specific tasks in organizational settings with demands for general theory and precise measurement, a challenging combination.

A historical survey (Banker & Kaufmann, 2004) identifies HCI as one of five major IS research streams, dating it to Ackoff's (1967) paper describing challenges in handling computer-generated information. There was some research into hands-on operator issues such as data entry and error messages, but for a decade most HCI work in Information Systems dealt with the users of information, typically managers. Research included the design of printed reports, but the drive for theory led to a strong focus on cognitive styles: individual differences in how people (notably managers) perceive and process information. HCI articles were published in the human factors-oriented IJMMS as well as management journals.

The sociotechnical approach to system design (Mumford, 1971) was a response to user difficulties and resistance. It involved educating representative workers to technological possibilities and involving them in design, in part to increase their acceptance of the resulting system. Late in this period, sophisticated views of the complex social and organizational dynamics around system adoption and use emerged (e.g., Kling, 1980; Markus, 1983).

## Programming: Subject of Study, Source of Change

Even programmers who were not hands-on users did of course interact with computers, and more than 1,000 research papers on variables affecting programming performance were published in the 1960s and 1970s (Baecker & Buxton, 1987, p. 147). Most studied the behavior of programmers in isolation, independent of organizational context. Influential reviews of this work included Gerald Weinberg's landmark *The Psychology of Computer Programming* in 1971, Ben Shneiderman's *Software Psychology* in 1980, and Beau Sheil's 1981 review of studies of programming notation (conditionals, control flow, data types), practices (flowcharting, indenting, variable naming, commenting), and tasks (learning, coding, debugging).

Software developers changed the field through invention. In 1970, Xerox Palo Alto Research Center (PARC) was founded to advance computer technology by developing new hardware, programming languages, and programming environments. It attracted researchers and system builders from the labs of Engelbart and Sutherland. In 1971, Allen Newell of Carnegie Mellon University proposed a project to PARC, launched three years later: "Central to the activities of computing—programming, debugging, etc.—are tasks that appear to be within the scope of this emerging theory [a psychology of cognitive behavior]" (Card & Moran, 1986, p. 183).

Like HUSAT, also launched in 1970, PARC had a broad charter. HUSAT focused on ergonomics, anchored in the tradition of nondiscretionary use, one component of which was the human factors of computing. PARC focused on computing, anchored in visions of discretionary use, one component of which was also the human factors of computing. Researchers at PARC, influenced by cognitive psychology, extended the primarily perceptual-motor focus of human factors to higher-level cognition. HUSAT, influenced by sociotechnical design, extended human factors by considering organizational factors.

## Computer Science: A New Discipline

Computer Science departments emerged in the mid-1960s. Some originated in engineering, others in applied mathematics. From engineering, computer graphics was a specialization of particular relevance to HCI. Applied math was the background of many early researchers in artificial intelligence, which has interacted with HCI in complex ways in subsequent years.

The expensive early machines capable of interesting work were funded without regard to cost by branches of the military. Technical success was the sole evaluation criterion (Norberg & O'Neill, 1996). Directed by Licklider, Sutherland, and their successors, ARPA played a major role. The need for heavy funding concentrated researchers at a few centers. These bore little resemblance to that era's batch and timeshared business computing environments. User needs differed: technically savvy hands-on users in research settings did not press for low-level interface enhancements.

The computer graphics and AI perspectives that developed in these centers differed from those of HCI researchers who focused on less expensive, more widely deployed systems. Computer graphics and AI required processing power—hardware advances meant declining cost for the same high level of computation. For HCI researchers, hardware advances meant greater computing capability at the same low price. Only later would this difference diminish, when widely-available machines could support graphical interfaces and some AI programs. Despite this gap, between 1965 and 1980 some computer science researchers focused on interaction, not surprising given that interaction was part of the early visions.

*Computer Graphics: Realism and Interaction.* In 1968 Sutherland joined David Evans to establish an influential computer graphics lab at the University of Utah. The Utah Computer Science department was founded in 1965, part of the first wave. It contributed to the western migration as graduates of the lab, including Alan Kay and William Newman (and later Jim Blinn and Jim Clark), went to California. Most graphics systems at the time were built on the DEC PDP-1 and PDP-7. These expensive machines—the list price of a high-resolution display alone was over $100,000 in today's dollars—were in principle capable of multitasking, but in practice a graphics program generally required all the processor's cycles.

In 1973, the Xerox Alto arrived, a powerful step toward realizing Alan Kay's vision of computation as a medium for personal computing (Kay and Goldberg, 1977). The Alto was too expensive to be widely used—it was never commercialized—and not powerful enough to support high-end graphics research, but it supported graphical interfaces of the kind Engelbart had prototyped. In doing so, the Alto signaled the approach of inexpensive, interactive, personal machines capable of supporting graphics. Computer graphics researchers had to decide whether to focus on high-end graphics or on more primitive features that would soon run on widely affordable machines.

William Newman, co-author in 1973 of the influential *Principles of Interactive Computer Graphics*, described the shift: "Everything changed—the Computer Graphics community got interested in realism, I remained interested in interaction, and I eventually found myself doing HCI" (personal communication). He was not alone. Other graphics researchers whose focus shifted to broader interaction issues included Ron Baecker and Jim Foley. Foley and Wallace (1974, p. 462) identified requirements for designing "interactive graphics systems whose aim is good symbiosis between man and machine." The shift was gradual: Eighteen papers in the first SIGGRAPH conference, in 1974, had "interactive" or "interaction" in their titles. A decade later, there would be none.

At Xerox, Larry Tesler and Tim Mott recognized that the Alto could support a graphical interface accessible to untrained people. The latter point had not been important given the prior focus on trained, expert performance. By early 1974 Tesler and Mott had developed the GYPSY text editor. GYPSY and Xerox's Bravo editor developed by Charles Simonyi preceded

and influenced Microsoft Word (Hiltzik, 1999).

The focus on interaction was highlighted in 1976, when SIGGRAPH sponsored a two-day workshop in Pittsburgh titled "User Oriented Design of Interactive Graphics Systems." Participants who were later active in CHI included Jim Foley, William Newman, Ron Baecker, John Bennett, Phyllis Reisner, and Tom Moran. J.C.R. Licklider and Nicholas Negroponte presented vision papers. The conference was managed by the chair of Pittsburgh's Computer Science Department. One participant was Anthony Debons, Licklider's friend who had helped build Pittsburgh's world-renowned Information Science program. UODIGS'76 arguably marked the end of a visionary period, embodying an idea whose time had not quite yet come. Licklider saw it clearly:

Interactive computer graphics appears likely to be one of the main forces that will bring computers directly into the lives of very large numbers of people during the next two or three decades. Truly user-oriented graphics of sufficient power to be useful to large numbers of people has not been widely affordable, but it will soon become so, and, when it does, the appropriateness and quality of the products offered will to a large extent determine the future of computers as intellectual aids and partners of people. (Licklider, 1976, p. 89.)

UODIGS was not repeated. Despite the stature of the participants, the 150-page proceedings was not cited. Not until 1981 was another "user oriented design" conference held, after which they were held every year. Application of graphics was not quite at hand; most HCI research remained focused on interaction driven by commands, forms, and full-page menus.

*Artificial Intelligence: Winter follows summer.* In the late 1960s and early 1970s, AI burst onto the scene, promising to transform HCI. It did not go as expected. Logically, AI and HCI are closely related. What are intelligent machines for if not to interact with people? AI research has influenced HCI: speech recognition and natural language are perennial HCI topics; expert, knowledge-based, adaptive and mixed-initiative systems have been tried, as have applications of production systems, neural nets, and fuzzy logic. Today, human-robot interaction and machine learning are attracting attention.

Although some AI features make it into systems and applications, frequent predictions that powerful machines would bring major AI technologies into wide use, and thus into the focus of HCI research, were not borne out. AI did not come into focus in HCI, and AI researchers showed limited interest in HCI.

To piece this together requires a brief review of early AI history. The term *artificial intelligence* first appeared in a 1955 call by John McCarthy for a meeting on machine intelligence that was held in Dartmouth. In 1956, Alan Turing's prescient essay, "Computing Machinery and Intelligence," attracted attention when reprinted in *The World of Mathematics*. (It was first published in 1950, as were Claude Shannon's "Programming a Computer for Playing Chess" and Isaac Asimov's *I, Robot,* which explored his three laws of robotics.) Newell and Simon's logic theory machine appeared in 1956; they then focused on developing a general problem solver. McCarthy invented the LISP programming language in 1958 (McCarthy, 1960).

Many AI pioneers were trained in mathematics and logic, where almost everything can be derived from a few axioms and a small set of rules. Mathematical ability is considered a high form of intelligence, even by non-mathematicians. AI researchers anticipated that machines that operate logically and tirelessly would make profound advances--applying a small set of rules to a limited number of objects. Early AI focused on theorem-proving and games and problems that had a strong logical focus, such as chess and go. McCarthy, who espoused predicate calculus as a foundation for AI, summed it up as follows:

As suggested by the term 'artificial intelligence,' we weren't considering human behavior except as a clue to possible effective ways of doing tasks. The only participants who studied human behavior were Newell and Simon. (The goal) was to get away from studying human behavior and consider the computer as a tool for solving certain classes of problems. Thus, AI was created as a branch of computer science and not as a branch of psychology. (McCarthy, 1988.)

Unfortunately, by ignoring psychology, mathematicians overlooked the complexity and inconsistency that mark human beings and our social constructs. Underestimating the complexity of intelligence, they overestimated the prospects for creating it artificially. Hyperbolic predictions and AI have been close companions. In the summer of 1949 the British logician and code-breaker Alan Turing wrote in the *London Times*:

I do not see why [the computer] should not enter any one of the fields normally covered by the human intellect, and eventually compete on equal terms. I do not think you can even draw the line about sonnets, though the comparison is perhaps a little bit unfair because a sonnet written by a machine will be better appreciated by another machine.

Optimistic forecasts by the 1956 Dartmouth workshop participants attracted considerable attention. When they collided with reality, a pattern was established that was to play out repeatedly. Hans Moravec (1998) wrote:

In the 1950s, the pioneers of AI viewed computers as locomotives of thought, which might outperform humans in higher mental work as prodigiously as they outperformed them in arithmetic, if they were harnessed to the right programs… By 1960 the unspectacular performance of the first reasoning and translation programs had taken the bloom off the rose.

An significant part of the pattern is that HCI thrives on resources that are freed when interest in AI declines. In 1960, with the bloom off the AI rose, the managers of MIT's Lincoln Labs looked for new uses for their massive (for the time) government-funded TX-0 and TX-2 computers. Ivan Sutherland's Sketchpad and early computer graphics were a result.

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The response to Sputnik reversed the downturn in AI prospects. J.C.R. Licklider, as director of ARPA's Information Processing Techniques Office from 1962-1964, provided extensive support for Computer Science in general and AI in particular. MIT's Project Mac, founded in 1963 by Marvin Minsky and others, initially received $13M per year, rising to $24M in 1969. ARPA sponsored the Artificial Intelligence Laboratory at Stanford Research Institute, AI research at CMU, and Nicholas Negroponte's Machine Architecture Group at MIT. A dramatic early achievement, SRI's Shakey the Robot, was featured in 1970 articles in *Life* (Darrach, 1970) and *National Geographic*. Given a simple but non-trivial task, Shakey could apparently go to the desired location, scan and reason about the surroundings, and move objects as needed to accomplish the goal (for Shakey at work, see http://www.ai.sri.com/shakey/).

In 1970, Negroponte outlined a case for machine intelligence: "Why ask a machine to learn, to understand, to associate courses with goals, to be self-improving, to be ethical—in short, to be intelligent?" He noted common reservations: "People generally distrust the concept of machines that approach (and thus why not pass?) our own human intelligence," and identified a key problem: "Any design procedure, set of rules, or truism is tenuous, if not subversive, when used out of context or regardless of context." This insight, that it is risky to apply algorithms without understanding the situation at hand, led Negroponte to a false inference: *"It follows that a mechanism must recognize and understand the context before carrying out an operation."* (p. 1, my italics.)

A perfectly reasonable alternative is that the mechanism is guided by humans who understand the context: Licklider's human-machine symbiosis. Overlooking this, Negroponte built a case for an ambitious research program:

Therefore, a machine must be able to discern changes in meaning brought about by changes in context, hence, be intelligent. And to do this, it must have a sophisticated set of sensors, effectors, and processors to view the real world directly and indirectly. . . . A paradigm for fruitful conversations must be machines that can speak and respond to a natural language. . . . But, the tete-à-tete (sic) must be even more direct and fluid; it is gestures, smiles, and frowns that turn a conversation into a dialogue. . . . Hand-waving often carries as much meaning as text. Manner carries cultural information: the Arabs use their noses, the Japanese nod their heads. . .

Imagine a machine that can follow your design methodology, and at the same time discern and assimilate your conversational idiosyncrasies. This same machine, after observing your behavior, could build a predictive model of your conversational performance. Such a machine could then reinforce the dialogue by using the predictive model to respond to you in a manner that is in rhythm with your personal behavior and conversational idiosyncrasies . . . The dialogue would be so intimate—even exclusive—that only mutual persuasion and compromise would bring about ideas, ideas unrealizable by either conversant alone. No doubt, in such a symbiosis it would not be solely the human designer who would decide when the machine is relevant. (pp. 1-13.)

The same year, Negroponte's MIT colleague Minsky went further, as reported in Life:

In from three to eight years we will have a machine with the general intelligence of an average human being. I mean a machine that will be able to read Shakespeare, grease a car, play office politics, tell a joke, and have a fight. At that point, the machine will begin to educate itself with fantastic speed. In a few months, it will be at genius level and a few months after that its powers will be incalculable. (Darrach, 1970, p. 60.)

Other AI researchers told Darrach that Minsky's timetable was ambitious:

Give us 15 years' was a common remark—but all agreed that there would be such a machine and that it would precipitate the third Industrial Revolution, wipe out war and poverty and roll up centuries of growth in science, education and the arts.

Such predictions were common. In 1960, Nobel laureate and AI pioneer Herb Simon had written, "Machines will be capable, within twenty years, of doing any work that a man can do." (p. 38). Five years later, I. J. Good, an Oxford mathematician, wrote, "the survival of man depends on the early construction of an ultra-intelligent machine" that "could design even better machines; there would then unquestionably be an 'intelligence explosion,' and the intelligence of man would be left far behind" (pp. 31-33).

The Darrach article ended by quoting Ross Quillian:

I hope that man and these ultimate machines will be able to collaborate without conflict. But if they can't, we may be forced to choose sides. And if it comes to choice, I know what mine will be. My loyalties go to intelligent life, no matter in what medium it may arise. (p. 68).

It is important to understand the anxieties of the time, as well as the consequences of such claims. The world had barely avoided a devastating thermonuclear war during the Cuban missile crisis of 1962. Leaders seemed powerless to defuse the Cold War. Responding to a sense of urgency, ARPA initiated major programs in speech recognition and natural language understanding in 1971.

Ironically, central to funding this research was a psychologist not wholly convinced by the vision. Citing a 1960 Air Force study that predicted that intelligent machines might take 20 years to arrive, J.C.R. Licklider noted that in this interval HCI would be useful: "That would leave, say, five years to develop man-computer symbiosis and 15 years to use it. The 15 may be 10 or 500, but those years should be intellectually the most creative and exciting in the history of mankind." Ten to five hundred years represents breathtaking uncertainty. Recipients of Licklider's funding were on the optimistic end of this spectrum.

Five years later, disappointed with the progress, ARPA discontinued speech and language support—for a while. In Eu-

rope, a similar story unfolded. Through the 1960s, AI research expanded in Great Britain. A principal proponent was Turing's former colleague Donald Michie. Then in 1973, the Lighthill Report, commissioned by the Science and Engineering Research Council, reached generally negative conclusions about AI's prospects for scaling up to address real-world problems. Almost all government funding was cut off.

The next decade was called an AI winter, a recurring season in which research funding is withheld due to disillusionment over unfulfilled promises. The bloom was again off the rose, but it would prove to be a hardy perennial (Grudin, 2009).


## Library Schools Embrace Information Science

Early Information Science and studies of "human information behavior" initiated in the 1960s and 1970s focused on scholarship and application in science and engineering (Fidel, 2010). The response to Sputnik proved that 'big science' research did not necessarily end when the war ended. Aligning their work with national priorities became a priority for many researchers.

The terms 'information science,' 'information technology,' and 'information explosion' swept into use as information became an unquestioned part of the future. The Pittsburgh and Georgia Tech programs flourished. Pittsburgh created the first Information Science Ph.D. program in the U.S. in 1970, identifying humans "as the central factor in the development of an understanding of information phenomena" (Aspray, 1999, p. 12). The program balanced behavioral sciences (psychology, linguistics, communications) and technical grounding (automata theory, computer science). In 1973, Pittsburgh established the first Information Science Department. Its program developed a very strong international reputation. Slowly, the emphasis shifted from behavior to technology. Upon being awarded a major NSF center grant in 1966, the Georgia Tech school expanded, and in 1970 became a Ph.D.-granting school rechristened Information and Computer Science.

In 1968, the American Documentation Institute became the American Society for Information Science, and two years later the journal *American Documentation* became *Journal of the American Society for Information Science*. In 1978 the ACM Special Interest Group on Information Retrieval (SIGIR) formed and launched an annual conference (titled "Information Storage and Retrieval" in this period), modeled on a 1971 conference. In 1984, the American Library Association belatedly embraced the i-word in creating the Association for Library and Information Science Education (ALISE), which convened an annual research conference.

By 1980, schools at over a dozen universities had added Information to their titles. Many were library school transitions. Delivery on the promise of transformative information technology lagged, however. For example, from 1965 to 1972 the Ford and Carnegie Foundations, NSF, DARPA, and the American Newspaper Publishers Association invested over $30 million in MIT's Project Intrex (Burke, 1998). The largest non-military information research project of its time, Intrex was to be the library of the future. Online catalogs were to include up to 50 index fields per item, accessible on CRT displays, with full text of books and articles converted to microfilm and read via television displays. None of this proved feasible.

Terminal-based computing costs declined. The ARPANET debuted in 1969, supported email in 1971 and file-sharing in 1973. This spurred visions of a 'network society' of the future (Hiltz & Turoff, 1978). As an aside, the technological optimism of AI and networking proponents of this era lacks the psychological insight and nuance of E.M. Forster, who in 1909 anticipated both developments in his remarkable story *The machine stops.*


# 1980–1985: DISCRETIONARY USE COMES INTO FOCUS

In 1980, most people in HF&E and IS focused on the down-to-earth business of making efficient use of expensive mainframes. Almost unnoticed was the start of a major shift. Less expensive but highly capable minicomputers based on LSI technology enabled Digital Equipment Corporation, Wang Laboratories, and Data General to make inroads into the mainframe market. At the low end, home computers gained traction. Students and hobbyists were drawn to these minis and micros, creating a population of hands-on discretionary users. There were experimental trials of online library catalogs and electronic journals.

Then, between 1981 and 1984, a flood of innovative and powerful computers were released: Xerox Star, IBM PC, Apple Lisa, Lisp machines from Symbolics and LMI (Lisp Machines, Inc.), workstations from Sun Microsystems and Silicon Graphics, and the Apple Macintosh. On January 1, 1984, AT&T's breakup into competing companies took effect. AT&T had more employees and more customers than any other U.S. company. It was a monopoly: Neither its customers nor its employees had discretion in technology use. AT&T and its Bell Laboratories research division had focused on training and efficiency through Human Factors. Suddenly freed from a ban on entering the computer business, AT&T launched the ill-fated Unix PC in1985. AT&T and the new regional operating companies now faced customers who had choices, and their HCI focus broadened accordingly (Israelski & Lund, 2003).

In general, lower-priced computers created markets for shrinkwrap software. For the first time, computer and software companies targeted significant numbers of non-technical hands-on users who received little or no formal training. It had taken twenty years, but early visions were being realized! Non-programmers were choosing to use computers to do their work.

The psychology of discretionary users intrigued two groups: (i) psychologists who liked to use computers, and (ii) technology companies who wanted to sell to discretionary users. Result: Computer and telecommunication companies hired a lot of experimental psychologists.

## Discretion in Computer Use

Our lives move through the continuum bracketed by the assembly line nightmare of *Modern Times* and the utopian vision of completely empowered individuals. To use a technology or not to use it: Sometimes we have a choice, other times we don't. On the phone, we may have to wrestle with speech recognition and routing systems. At home, computer use may be largely discretionary. The workplace often lies in-between: Technologies are prescribed or proscribed, but we ignore some injunctions or obtain exceptions, we use some features but not others, and we join with colleagues to press for changes.

For early computer builders, work was more a calling than a job, but operation required a staff to carry out essential if less interesting tasks. For the first half of the computing era, most hands-on use was by people with a mandate. Hardware innovation, more versatile software, and steady progress in understanding the psychology of users and tasks—and transferring that understanding to software developers—led to hands-on users who had more choice in how they worked. Rising expectations played a role—people learned that software is flexible and expected it to be more congenial. Competition among vendors produced alternatives. With more emphasis on marketing to consumers came more emphasis on user-friendliness.

Discretion is not all-or-none. No one must use a computer, but many jobs and pastimes require it. People can resist, sabotage, or quit the job. However, a clerk or systems administrator has less discretion than someone using technology for leisure activity. For an airline reservation clerk, computer use is mandatory. For a traveler booking a flight, computer use is discretionary. These differences, and the shift toward greater discretion, is at the heart of the history of HCI.

The shift was gradual. Thirty years ago, John Bennett (1979) predicted that discretionary use would lead to more emphasis on usability. The 1980 book *Human Interaction with Computers,* edited by Harold Smith and Thomas Green, perched on a cusp. An article by Jens Rasmussen, "the human as a systems component," covered the nondiscretionary perspective. One-third of the book covered research on programming. The remainder addressed "non-specialist people," discretionary users who are not computer-savvy. Smith and Green wrote, "It's not enough just to establish what computer systems can and cannot do; we need to spend just as much effort establishing what people can *and want to do.*" (p. viii, italics in original.)

A decade later, Liam Bannon (1991) noted broader implications of a shift "from human factors to human actors." The trajectory is not always toward choice. Discretion can be curtailed—for example, word processor use is now often a job requirement, not an alternative to using a typewriter. Even in an era of specialization, customization, and competition, the exercise of choice varies over time and across contexts. Discretion is only one factor, but an analysis of its role casts light on how HCI efforts differ and why they have remained distinct.

## Minicomputers and Office Automation

Cabinet-sized mini-computers that could support several people were available from the mid-1960s. By the late 1970s, super-minis such as the VAX 11/780 supported integrated suites of productivity tools. In 1980, Digital Equipment Corporation, Data General, and Wang Laboratories were growth companies near Boston.

A minicomputer could handle a database of moderate size or personal productivity tools. Users sat at terminals. With 'dumb terminals,' the central processor handled each keystroke. Other terminals had a processor that supported a user who entered a screenfull of data, which was then on command sent as a batch to the central processor. These minis could provide a small group (or 'office') with file sharing, word processing, spreadsheets, email, and output devices. They were marketed as 'office systems,' 'office automation systems,' or 'office information systems.'

The 1980 Stanford International Symposium on Office Automation marked the emergence of a research field that was influential for a decade, then faded away. Douglas Engelbart contributed two papers to the proceedings (Landau, Bair & Siegman, 1982). The same year, the American Federation of Information Processing Societies (AFIPS, the parent organization of ACM and IEEE at the time) held the first of seven annual Office Automation conferences and product exhibitions. Also in 1980, ACM formed a Special Interest Group on Office Automation (SIGOA), which two years later launched the biennial Conference on Office Information Systems (COIS). In 1983 *ACM Transactions on Office Information Systems (TOOIS)* emerged, one year after the independent journal *Office: Technology and People.*

You might ask, "what is all this with offices?" Minicomputers brought down the price of computers to fit into the budget of a small work-group: an 'office.' (The attentive reader will anticipate: The personal computer era is approaching!) Office Information Systems, which focused on the use of minicomputers, was positioned alongside Management Information Systems, which focused on mainframes. Its scope was reflected in the charter of *TOOIS:* database theory, artificial intelligence, behavioral studies, organizational theory, and communications. Minis were accessible to database researchers. Digital's PDP series was a favorite of AI researchers until LISP machines flourished. Minis were familiar to behavioral researchers who used them to run and analyze psychology experiments. Computer-mediated communication (CMC) was an intriguing new capabil-

ity: Networking was still rare, but people at different terminals of a minicomputer could exchange email or chat in real time. Minis became interactive computers of choice for many organizations. As a consequence, Digital became the second largest computer company in the world and Dr. Wang the fourth wealthiest American.

The researchers were discretionary users, but few office workers chose their tools. The term 'automation' was challenging and exciting to researchers, but conjured up less pleasant images for office workers. Some researchers, too, preferred Engelbart's focus on augmentation rather than automation.

Papers in the SIGOA newsletter, COIS, and *TOOIS* included technical work on database theory, a modest number of AI papers (the AI winter had not yet ended), decision support and CMC papers from the IS community, and behavioral studies by researchers who later joined CHI. IS papers were prevalent in the newsletter, technical papers in *TOOIS*, which also published numerous behavioral studies until the journal *HCI* started in 1985.

Although OA/OIS research was eventually absorbed by other fields, it identified and called attention to important emerging topics, including hypertext, computer-mediated communication, and collaboration support generally. OIS work was conceptually linked to the technical side of Information Science, notably information retrieval and language processing.
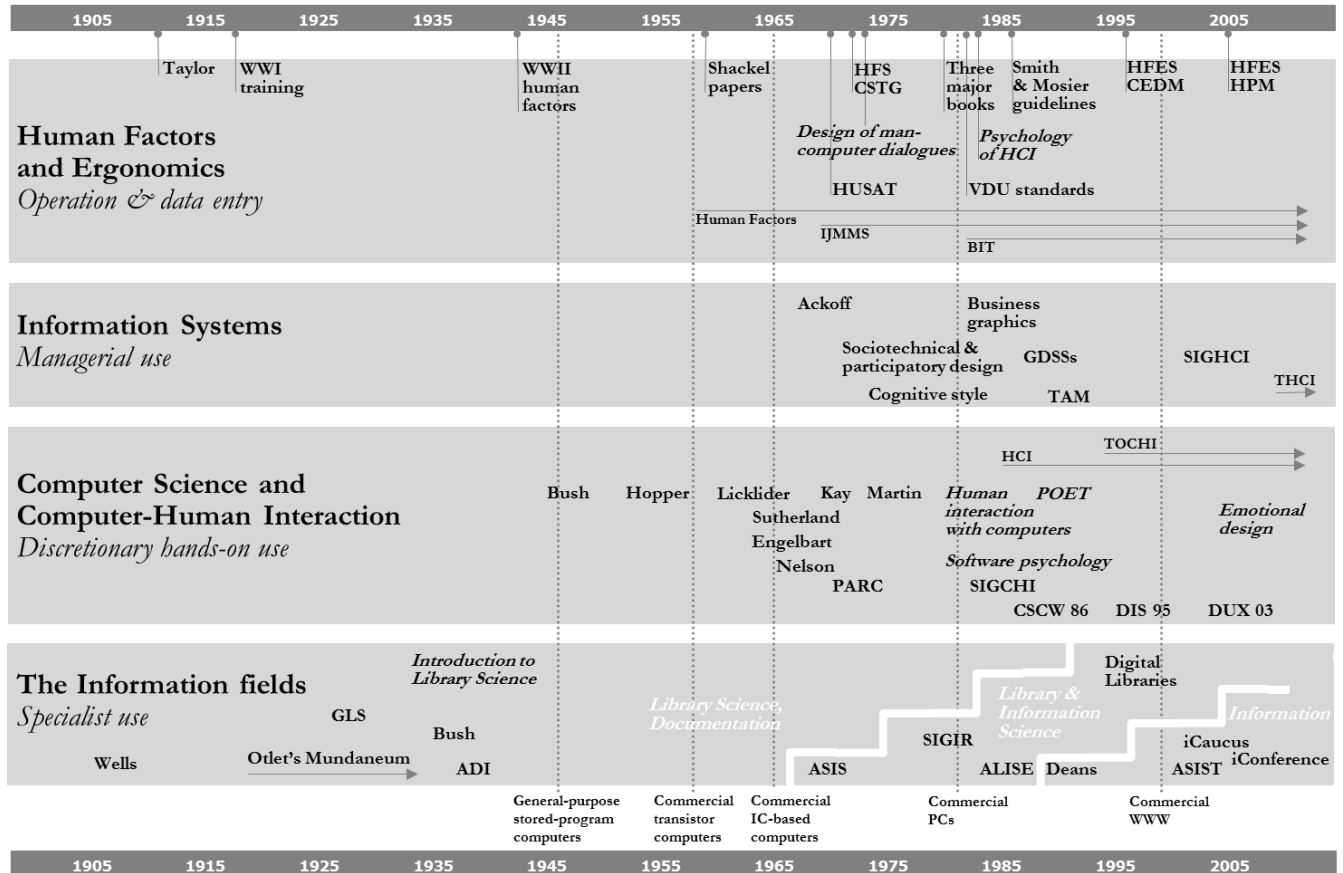


**Figure 1. Four fields with major HCI research threads. Acronym expansions are in the text.**

## The Formation of ACM SIGCHI

Figure 1 identifies research fields that directly bear on HCI. Human Factors and Information Systems have distinct subgroups that focus on broad use of digital technologies. Relevant Computer Science research is concentrated in CHI, the subgroup primarily concerned with discretionary hands-on computer use. Other computer science influences--computer graphics, artificial intelligence, office systems--are described in the text but not included in Figure 1. The fourth field, Information, began as support for specialists. Today it may exert the broadest influence of all.

Decreasing microcomputer prices encouraged discretionary hobbyists. In 1980, as IBM prepared to launch the PC, a groundswell of attention to computer user behavior was building. IBM, which like many hardware companies had not sold software separately, had decided to make software a product focus. Several cognitive psychologists joined an IBM group that included John Gould, who had been publishing human factors research since the late 1960s. They initiated empirical studies of programming and studies of software design and use. Other psychologists who in 1980 led recently formed HCI groups

were Phil Barnard at the Medical Research Council Applied Psychology Unit in Cambridge, England; Tom Landauer at Bell Labs; Donald Norman at the University of California, San Diego; and John Whiteside at Digital Equipment Corp.

Xerox PARC and CMU collaborators continued research in several areas and introduced an exceptionally influential project, described below. The 1981 Star, with its carefully designed graphical user interface, was not a commercial success (nor were a flurry of GUIs that followed, including the Apple Lisa), but it influenced researchers and developers—and the Macintosh.

*Communications of the ACM* created a "Human Aspects of Computing" department in 1980. The next year, Tom Moran edited a special issue of *Computing Surveys* on "The Psychology of the Computer User." Also in 1981, the ACM Special Interest Group on Social and Behavioral Science Computing (SIGSOC) extended its workshop to cover interactive software design and use. In 1982 a conference in Gaithersburg, Maryland on "Human Factors in Computing Systems" was unexpectedly well-attended. Shortly afterwards, SIGSOC shifted its focus to Computer- Human Interaction and its name to SIGCHI (Borman, 1996).

In 1983, the first CHI conference drew more than 1,000 people. Half of the 58 papers were from the seven research labs just mentioned. Cognitive psychologists in industry dominated the program, although the Human Factors Society co-sponsored the conference and contributed the program chair Richard Pew, committee members Sid Smith, H. Rudy Ramsay, and Paul Green, and several presenters. Brian Shackel and HFS president Robert Williges gave tutorials the first day. The International Conference on Human-Computer Interaction (INTERACT), first held in London in 1984 and chaired by Shackel, drew HF&E and CHI researchers.

The first profession to become discretionary hands-on users was computer programming, as paper coding sheets were discarded in favor of text editing at interactive terminals, PCs, and small minicomputers. Therefore, many early CHI papers, by Ruven Brooks, Bill Curtis, Thomas Green, Ben Shneiderman, and others, continued the psychology-of-programming research thread. IBM Watson researchers also contributed, as noted by John Thomas:

One of the main themes of the early work was basically that we in IBM were afraid that the market for computing would be limited by the number of people who could program complex systems, so we wanted to find ways for "nonprogrammers" to be able, essentially, to program. (Personal communication, October 2003)

Psychologists and studies of editing were prevalent: Thomas Green remarked at INTERACT'84 that "text editors are the white rats of HCI." But as personal computing spread, experimental methods were applied to studying other contexts in which discretionary use appeared. Studies of programming gradually disappeared from HCI conferences.

CHI focused on novice use. Initial experience is particularly important to discretionary users and to the vendors developing software for them. Novice users are also a natural focus when studying new technologies and a critical focus when more people take up computing each year than did the year before.

Routinized heavy use was still widespread. Databases were used by airlines, banks, government agencies, and other organizations. This hands-on activity was rarely discretionary. Managers oversaw development and analyzed data, leaving data entry and information retrieval to people hired for those jobs. Improving skilled data handling was a human factors undertaking. CHI studies of database use were few—I count three over a decade, all focused on novice or casual use.

Fewer European companies produced mass-market software. European research favored in-house development and use. In his perceptive essay cited above, Bannon urged that more attention be paid to discretionary use, yet criticized CHI's heavy emphasis on initial experiences, perhaps reflecting the European perspective. At Loughborough University, HUSAT focused on job design (the division of labor between people and systems) and collaborated with the Institute for Consumer Ergonomics, particularly on product safety. In 1984, Loughborough initiated an HCI graduate program drawing on human factors, industrial engineering, and computer science.

The early visionaries were not familiar to many of the CHI researchers who helped realize some of the visions. The 633 references in the 58 papers presented at CHI 83 included many authored by cognitive scientists, but Bush, Sutherland, and Engelbart were not cited. More computer scientists familiar with the early work entered CHI a few years later. The psychologists eventually discovered and identified with the pioneers, who shared their concern with discretionary use. This conceptual continuity bestowed legitimacy on a young enterprise that sought to establish itself academically and professionally.

CHI and Human Factors Diverge

*Hard science, in the form of engineering, drives out soft science, in the form of human factors.* -- Newell and Card (1985, p. 212)

Between 1980 and 1985, Card, Moran, and Newell (1980a, 1980b) introduced a "keystroke-level model for user performance time with interactive systems," followed by the cognitive model GOMS—goals operators, methods, and selection rules—in their landmark 1983 book, *The Psychology of Human-Computer Interaction.* This work was highly respected by the cognitive psychologists prevalent in CHI at the time. However, these models did not address discretionary, novice use. They focused on the repetitive expert use studied in Human Factors. In fact, GOMS was explicitly positioned to counter the stimu-

lus-response bias of Human Factors research:

Human-factors specialists, ergonomists, and human engineers will find that we have synthesized ideas from modern cognitive psychology and artificial intelligence with the old methods of task analysis. . . . The user is not an operator. He does not operate the computer, he communicates with it. . . . (p. viii)

Newell and Card (1985) noted that human factors had a role in design, but continued:

Classical human factors . . . has all the earmarks of second-class status. (Our approach) avoids continuation of the classical human-factors role (by transforming) the psychology of the interface into a hard science. (p. 221)

In 2004, Card noted in an email discussion:

Human factors was the discipline we were trying to improve. . . . I personally changed the (CHI conference) call in 1986, so as to emphasize computer science and reduce the emphasis on cognitive science, because I was afraid that it would just become human factors again.

Ultimately, human performance modeling drew a modest but fervent CHI following. Key goals differed from those of many practitioners and other researchers. "The central idea behind the model is that the time for an expert to do a task on an interactive system is determined by the time it takes to do the keystrokes," wrote Card, Moran & Newell (1980b, p. 397). Modeling was extended to a range of cognitive processes, but was most useful in helping to design for nondiscretionary users, such as telephone operators engaged in repetitive tasks (e.g., Gray et al., 1990). Its role in augmenting human intellect was unclear.

CHI and Human Factors moved apart, although "Human Factors in Computing Systems" remains the CHI conference subtitle. They were never highly integrated. Most of the cognitive psychologists had turned to HCI after earning their degrees and were unfamiliar with the Human Factors literature. The Human Factors Society did not again cosponsor CHI. Its researchers disappeared from the CHI program committee. Most CHI researchers who previously published in the Human Factors conference and journal shifted to CHI, *Communications of the ACM,* and the journal *Human-Computer Interaction*, which was launched in 1985 by Thomas Moran and published by Erlbaum, a publisher of psychology books and journals.

The shift was reflected at IBM T.J. Watson Research Center. John Gould and Clayton Lewis authored a CHI 83 paper that nicely defined the CHI focus on user-centered, iterative design based on prototyping. Watson cognitive scientists helped shape CHI, but Gould's principal focus remained human factors; he served as HFS president four years later. Symbolically, in 1984, the Human Factors Group at Watson faded away and a User Interface Institute emerged.

CHI researchers, wanting to be identified with 'hard' science or engineering, adopted the terms 'cognitive engineering' and 'usability engineering.' In the first paper presented at CHI 83, "Design Principles for Human–Computer Interfaces," Donald Norman applied engineering techniques to discretionary use, creating 'user satisfaction functions' based on technical parameters. These functions would not hold up long—people are fickle, yesterday's satisfying technology is not as gratifying today—but it would be years before CHI loosened its identification with engineering.


## Workstations and Another AI Summer

High-end workstations from Apollo, Sun, and Silicon Graphics appeared between 1981 and 1984. Graphics researchers no longer had to flock to heavily-financed labs (notably MIT and Utah in the 1960s; MIT, NYIT, and PARC in the 1970s). The workstations were too expensive to reach a mass market, so graphics research that focused on photorealism and animation, which required the processing power of these machines, did not directly exert a broad influence on HCI.

The Xerox Star (formally named Office Workstation), Apple Lisa, and other commercial GUIs appeared, but when the first CHI conference was held in December, 1983, none were succeeding. They cost too much or ran on processors that were too weak to exploit graphics effectively.

In 1981, Symbolics and LMI introduced workstations optimized for the Lisp programming language favored by most AI researchers. The timing was fortuitous. In October of that year, a conference on Next Generation Technology was held in the National Chamber of Commerce auditorium in Tokyo, and in 1982 the Japanese government established the Institute for New Generation Computer Technology (ICOT) and a ten-year Fifth Generation project focused on AI. AI researchers in Europe and the U.S. sounded the alarm. Donald Michie of Edinburgh saw a threat to western computer technology, and in 1983, Ed Feigenbaum of Stanford and Pamela McCorduck wrote:

The Japanese are planning the miracle product. . . . They're going to give the world the next generation—the Fifth Generation—of computers, and those machines are going to be intelligent. . . . We stand, however, before a singularity, an event so unprecedented that predictions are almost silly. . . . Who can say how universal access to machine -intelligence—faster, deeper, better than human intelligence—will change science, economics, and warfare, and the whole intellectual and sociological development of mankind? (pp. 8-9, 287.)

Parallel distributed processing (often called 'neural net') models also seized the attention of researchers and media. Used

to model phenomena including signal detection, motor control, and semantic processing, neural nets represented conceptual and technical advances over earlier AI work on perceptrons. Their rise was tied to the new generation of minicomputers and workstations, which had the power to support simulation experiments. Production systems, a computer-intensive AI modeling approach with a psychological foundation, developed at CMU, also gained the attention of researchers.

These developments triggered an artificial intelligence gold rush. As with actual gold rushes, most of the money was made by those who outfitted and provisioned the prospectors, although generous government funding again flowed to the actual researchers. The European ESPRIT and UK Alvey programs invested over $200M per year starting in 1984 (Oakley, 1990). In the United States, funding for the DARPA Strategic Computing AI program, begun in 1983, rose to almost $400M in 1988 (Norberg & O'Neill, 1996). Investment in AI by 150 U.S. companies was estimated at about $2B in 1985 (Kao, 1998).

The unfulfilled promises of the past led to changes this time around. General problem solving was emphasized less, domain-specific problem solving was emphasized more. Terms such as intelligent knowledge-based systems, knowledge engineering, expert systems, machine learning, language understanding, image understanding, neural nets, and robotics were often favored over AI.

In 1983, Raj Reddy of CMU and Victor Zue of MIT criticized the mid-1970s abandonment of speech processing research, and soon funds were again plentiful for these areas (Norberg and O'Neill, 1996, p. 238). Johnson (1985) estimated that 800 corporate employees and 400 academics were working on natural language processing research. Commercial NLU interfaces to databases such as AI Corporation's Intellect and Microrim Clout appeared.

AI optimism is illustrated by two meticulously researched Ovum reports on speech and language processing (Johnson, 1985; Engelien & McBride, 1991). In 1985, speech and language product "revenue" was $75 million, comprising mostly income from grants and investor capital. That year, Ovum projected that sales would reach $750 million by 1990 and $2.75 billion by 1995. In 1991, sales were under $90 million, but hope springs eternal and Ovum forecast $490 million for 1995 and $3.6 billion for 2000.

U.S. corporations banded together, jointly funding the Microelectronics and Computer Technology Corporation (MCC). U.S. antitrust laws were relaxed to facilitate this cooperation. MCC embraced AI, reportedly becoming the leading customer for both Symbolics and LMI. MCC projects included two parallel NLU efforts, work on intelligent advising, and CYC (as in "encyclopedic," and later spelled Cyc), Douglas Lenat's ambitious project to build a common-sense knowledge base that other programs could exploit. In 1984, Lenat predicted that by 1994 CYC would be intelligent enough to educate itself. Five years later CYC was reported to be on schedule and about to "spark a vastly greater renaissance in [machine learning]" (Lenat, 1989, p. 257).

Knowledge engineering involved human interaction. This could have brought AI closer to HCI, but AI researchers interested in representation and reasoning were frustrated by the difficulty of eliciting knowledge from experts. Many AI systems were aimed at non-discretionary use, so this created opportunities for HF&E, especially in Europe, where funding directives dictated work that spanned technical and behavioral concerns. *International Journal of Man-Machine Studies* became a major outlet for both HF&E and AI research in the 1980s.

AI interaction with CHI was limited. CHI'83 and CHI'85 had sessions on speech and language, cognitive modeling, knowledge-based help, and knowledge elicitation, but in general, AI technologies did not succeed in the marketplace. Before it disappeared, AI Corporation's primary customer for the database interface Intellect was the government. Few AI researchers and developers worried about interaction details. For example, they loved powerful tools such as EMACS and UNIX and forgot the painful weeks that they had invested in learning the badly-designed command languages.

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## 1985–1995: GRAPHICAL USER INTERFACES SUCCEED

"There will never be a mouse at the Ford Motor Company."
—High-level acquisition manager, 1985 (personal communication)

Graphical user interfaces were a disruptive revolution when they succeeded commercially. As with previous disruptive shifts to stored programs and to interaction based on commands, full-screen forms and full-screen menus, some people were affected before others. GUIs were particularly attractive to consumers, to new or casual users. Their success immediately transformed CHI, but only after Windows 3.0 succeeded in 1990 did GUIs influence the government agencies and business organizations that are the focus of HF&E and IS researchers. And by 1990, the technology was better understood and thus less disruptive. The early 1990s also saw the maturation of local area networking and the Internet, producing a second transformation: computer-mediated communication and information sharing.

## CHI Embraces Computer Science

Apple launched the Macintosh with a 1984 Super Bowl ad describing office work, but sales did not follow and in mid-1985 Apple was in trouble. Then Macs appeared with four times as much RAM, sufficient to manage Aldus PageMaker, Adobe Postscript, the Apple LaserWriter, and Microsoft's Excel and Word for Macintosh as they were released. The more powerful Mac Plus arrived in January, 1986. Rescued by hardware and software advances, the Mac succeeded where many commercial GUIs before it had not. It was popular with consumers and became the platform for desktop publishing.

Even within CHI, GUIs were initially controversial. They had disadvantages: an extra level of interface code increased development complexity and created reliability challenges; they consumed processor cycles and distanced users from the underlying system that, many believed, experienced users would eventually have to master. Carroll and Mazur (1986) showed that GUIs confused and created problems for people familiar with existing interfaces. An influential essay on direct manipulation interfaces, Hutchins, Hollan, and Norman (1986, p. 119), concluded, "It is too early to tell" how GUIs would fare. GUIs could well prove useful for novices, they wrote, but "we would not be surprised if experts are *slower* with Direct Manipulation systems than with command language systems" (italics in original). Because most prior HCI research had focused on expert use, this valid insight seemed significant. However, it was first-time use that proved critical in the rapidly expanding consumer market. Hardware and software improvements overcame the other difficulties. GUIs were here to stay, and effects within CHI came quickly. Active topics of research, including command naming, text editing, and the psychology of programming, were abandoned. More technical topics such as 'user interface management systems' became significant.

Viewed from a higher plane, psychology gave way to computer science as the driving force in interaction design. Researchers had strived for a comprehensive, theoretical, psychological framework based on formal experiments (Newell & Card, 1985; Carroll & Campbell, 1986; Long, 1989; Barnard, 1991). Such a framework was conceivable for constrained command- and form-based interaction, but could not be scaled to design spaces that included color, sound, animation, and an endless variety of icons, menu designs, and window arrangements. The new mission was to identify the most pressing problems and find satisfactory rather than optimal solutions. Rigorous experimentation, a skill of cognitive psychologists, gave way to quicker, less precise assessment methods, championed by Jakob Nielsen (1989; Nielsen & Molich, 1990).

Exploration of the dynamically evolving, unconstrained design space required software engineering expertise. The late 1980s saw an influx of computer scientists to the CHI community. HCI entered the curricula of many Computer Science departments. Many computer scientists working on interactive graphics saw CHI as a natural home, as did software engineers interested in interaction and some AI researchers working on speech recognition, language understanding, and expert systems. In 1994 ACM launched *Transactions on Computer-Human Interaction.* Early PCs and Macs were not easily networked, but as local area networks spread, CHI's focus expanded to include collaboration support. This brought it into contact with efforts in MIS and Office Automation research, discussed below. As noted above, computer scientists brought along knowledge of early pioneering work that was previously unknown to many cognitive scientists.

## HF&E Maintains a Nondiscretionary Use Focus

HF&E research continued to respond to the needs of government agencies, the military, aviation, and telecommunications. Governments are the largest consumers of computing, for census, tax, social security, health and welfare, power plant operation, air traffic control, ground control for space missions, military logistics, text and voice processing for intelligence, and so on. The focus is on skilled use—most users are assigned technology and trained if necessary. For routine data entry and other tasks, improvements that may not affect discretionary users can make a big difference. Small efficiency gains in individual transactions can yield large benefits over time. After CHI formed, the Human Factors Society undertook a study to see how it would affect membership in its Computer Systems Technical Group. An unexpectedly small overlap was found (Richard Pew, personal communication, 9/15/2004).

Government agencies promoted the development of ergonomic standards to help in defining system requirements for competitive bidding while remaining at arms' length from potential developers, who of course better understand technical possibilities and helped with standards development. Compliance with standards could then be specified in a contract. In 1986, Sid Smith and Jane Mosier published the last of a series of government-sponsored interface guidelines. Nine hundred and forty-four design guidelines were organized into sections titled Data Entry, Data Display, Data Transmission, Data Protection, Sequence Control, and User Guidance. The authors recognized that GUIs would expand the design space beyond the reach of this already cumbersome document that omitted icons, pull-down and pop-up menus, mice button assignments, sound, animation, and so on. Smith and Mosier foresaw that requirements definition must shift to specify predefined interface styles and design processes rather than features that would be built from scratch.

DARPA's heavily-funded Strategic Computing AI program set out to develop an Autonomous Land Vehicle, a Pilot's Associate, and a Battle Management system. All raised human factors research issues. These systems were to include interactive technologies such as speech recognition, language understanding, and heads-up displays. People might avoid these technologies when given a choice, but pilots, those guiding autonomous vehicles, and officers under stressful conditions might have no better alternative. Speech and language technologies have other non-discretionary potential, some of it civilian: by translators and intelligence analysts, when a phone system provides no alternative, when a disability limits keyboard

use or hands are otherwise occupied.


IS Extends Its Range

Although graphical user interfaces were not quickly adopted by organizations, spreadsheets and business graphics (charts and tables) were important to managers, and thus foci of Information Systems research. Remus (1984) contrasted tabular and graphic presentations, Benbasat and Dexter (1985) added color as a factor, although color displays were rare in the1980s. Many studies contrasted on-line and paper presentation, because most managers worked with printed reports. Although research into individual cognitive styles was abandoned in the early 1980s following a devastating critique (Huber, 1983), the concept of cognitive fit between task and tool was introduced to explain apparently contradictory results in the adoption literature (Vessey and Galletta, 1991).

A series of symposia on Human Factors in Information Systems was initiated in 1986 by Jane Carey, leading to several books (e.g., Carey, 1988). The topics included user interaction with information, design and development, and as corporate adoption of minicomputers and intranets matured, communication and collaboration, including studies of email use.

The involvement of end users in the development process was actively discussed in IS, but rarely practiced outside of the sociotechnical and participatory movements discussed below (Friedman, 1989). Hands-on managerial use was atypical in this period, but it was central to group decision support systems (GDSS) research. Central to GDSS was support for meetings, including brainstorming, idea organizing, and online voting features. GDSS emerged from decision support systems, aimed at supporting individual executives or managers, and evolved into group support systems. Computer-supported meeting facility research was conducted in the mid-1980s in several laboratories (e.g., Begeman et al., 1986; DeSanctis and Gallupe, 1987; Dennis et al., 1988). Extensive research at the University of Arizona is summarized in Nunamaker et al. (1997). These systems were initially too expensive to be mass-market products, hence the focus on 'decision-makers,' with research conducted primarily in schools of management, not computer science departments or software companies. GDSS was a major IS contribution to Computer Supported Cooperative Work (CSCW), discussed below. In 1990, three companies, including a University of Arizona spin-off and IBM, began marketing GDSSs, without much success.

The Technology Acceptance Model (TAM) introduced in Davis (1989) led to considerable IS research. TAM and its descendants focus on perceived usefulness and perceived usability to improve "white collar performance" that is "often obstructed by users' unwillingness to accept and use available systems" (p. 319). "An element of uncertainty exists in the minds of decision makers with respect to the successful adoption," wrote Bagozzi, Davis, and Warshaw (1992, p. 664). Although a managerial view of individual behavior, TAM was influenced by Davis's exposure to early CHI usability research.

TAM is probably the most cited HCI work in IS. Its success indicates that the view of hands-on computer use as non-discretionary was giving way as use spread to white-collar workers who could refuse to play. TAM's on perceived utility and usability brings into focus the contrast of CHI and IS: Consumers choose technologies that they are convinced will be useful, so CHI rarely considers utility at all and focuses on the *experience* of usability. TAM researchers focus on utility, but note that *perceptions* of usability could influence acceptance. CHI addressed usability a decade before TAM, albeit on measures of actual usability rather than perceived usability. Perception was a secondary 'user satisfaction' measure to CHI researchers, who believed (not entirely correctly) that measurable reduction in time, errors, questions, and training would eventually translate into positive perceptions. 'Acceptance,' the 'A' in TAM, is not in the CHI vocabulary. Discretionary users choose or adopt, they don't accept.

The IS and CHI communities rarely mixed. When CHI was over a decade old, *Harvard Business Review,* a touchstone for IS researchers, published "Usability: The new dimension of product design" (March, 1994). The article did not mention CHI at all. It concluded that "user-centered design is still in its infancy" (p. 149).


Collaboration Support: OIS Gives Way to CSCW

In the late 1980s, three research communities addressed small-group communication and information-sharing. (i) Office Automation/Office Information Systems, described earlier. (ii) IS researchers building systems to support organizational decision-making could, as computing costs declined, address group decision-making more generally. (iii) The proliferation of LAN networks enabled some CHI researchers to move from individual productivity software to the quest for 'killer apps' that would support teams.

The OA/OIS field had led the way, but it declined and was disappearing by 1995. The minicomputer, platform for most OIS research, did not survive competition from PCs and workstations. The concept of 'office' or group proved to be problematic: organizations and individuals are persistent entities with goals and needs, but small groups often have ambiguous membership and shift in character as members join or depart. People in an organization who need to communicate often fall under different budgets, complicating acquisition decisions unless a technology is made available organization-wide.

The rapid shift was reflected in terminology use. First, 'automation' fell out of favor. In 1986, ACM SIGOA shifted to SIGOIS (Office Information Systems) and the annual AFIPS OA conferences ended. By 1991, the term 'Office' followed: *Transactions on Office Information Systems* became *Transactions on Information Systems; Office: Information and People*

became *Information Technology and People*; and 'Conference on Office Information Systems' became 'Conference on Organizational Communication Systems' (with the awkward acronym 'COOCS,' later rechristened the GROUP Conference).

The AI summer, which contributed to the OA/OIS effort, ended when AI failed to meet expectations: Massive funding did not deliver a Pilot's Associate, an Autonomous Land Vehicle, or a Battle Management System for the military. Offices were not automated, either. CHI conference sessions on language processing diminished earlier, but sessions on modeling, adaptive interfaces, advising systems, and other uses of intelligence in interfaces increased through the 1980s before declining in the 1990s. AI funding became scarce, employment opportunities dried up, and conference participation dropped off.

Building on a 1984 workshop (Greif, 1985), the 1986 Computer Supported Cooperative Work conference brought together researchers from diverse disciplines interested in issues of communication, information sharing, and coordination. Participants came primarily from IS, OIS, CHI, distributed AI, and anthropology. Four of thirteen CSCW program committee members and many papers were from schools of management, with similar numbers from OIS.

The field coalesced in 1988. *Computer-Supported Cooperative Work,* edited by Irene Greif, was published, and SIGCHI sponsored the biennial North American CSCW conference. A European series (ECSCW) was initiated in 1989. With heavy participation from computer and software companies, North American CSCW had a small-group focus on networked individuals working on PCs, workstations, or minis, either within an organization or linked by ARPANET, bitnet, or other networks. European participation was from academia and government agencies. It focused on organizational use of technologies, but differed methodologically from most IS researchers in the U.S. Scandinavian influences, described in the next section, influenced both CSCW and ECSCW.

Just as human factors researchers left CHI after a few years, most IS researchers who were involved with CSCW left, starting in 1990. HICSS (the annual Hawaii International Conference on System Sciences) was more receptive to the groups support work and became a major IS pre-journal publication venue in this area. Some IS researchers participated in COOCS. Others contributed to the bi-annual Groupware conference series initiated in 1992. The split was not entirely amicable; an IS newsletter, *Groupware Report,* posted notices of many relevant conferences, but CSCW was not among them.

CSCW was challenged by the pace of technology change. In 1985, supporting a small team was a technical challenge; ten years later, the Web had arrived. Applications that provided awareness of the activity of distant collaborators was a celebrated achievement in the early 90s; several years later, dark linings to the silver cloud arose in the form of privacy concerns and information overload. Phenomena were carefully identified, such as a 'productivity paradox' in which IT investments were not returning benefits and health effects of Internet use on young people, that had vanished only a few years later. These changes brought European and North American CSCW into greater alignment. European CSCW had focused on organizational development and use, just as organizations were shifting to the commercial software focused on in North America. Meanwhile, North American CSCW was finding that collaboration could not be supported one team at a time, that organizational context was often important. Organizational behaviorists and theorists were thriving in their home disciplines, but ethnographers studying technology use, marginalized in traditional anthropology departments, were welcomed into CSCW.

Despite the challenges of building on sands swept by successive waves of technology innovation, CSCW remains a strong research area that attracts a broad swath of HCI researchers. Content ranges from the highly technical to thick ethnographies of workplace activity, from studies of instant messaging dyads to scientific collaboratories involving hundreds of people dispersed in space and time. The handbook chapter on Collaboration Technologies by Gary and Judy Olson covers the technical side in depth, with references to other CSCW resources.


Sociotechnical and Participatory Design

Predating this period were experiments in employing design methods to systematically involve specific people who would interact with a resulting system, typically non-discretionary users of systems developed by a large enterprise for its own use. As noted earlier, sociotechnical design (Mumford, 1971; 1976; Bjørn-Andersen & Hedberg, 1977) took a managerial perspective, whereas participatory or cooperative design, rooted in the Danish trade union movement, focused on empowering the eventual users (Nygaard, 1977). These efforts became widely influential following the publication of the proceedings of a 1985 conference held in Aarhus, Denmark (Bjerknes et al., 1987). Scandinavian influences also appeared in Human Factors (e.g., Rasmussen, 1986). Participatory design was a critique of IS approaches, yet the Scandinavians resonated with CHI researchers. Despite differences in culture, contexts of development (in-house vs. commercial product), and contexts of use (non-discretionary vs. discretionary), they shared the goal of empowering hands-on users. Most were also of the generation that grew up in the1960s, unlike the World War II generation that dominated HF&E and IS.


LIS: An Incomplete Transformation

Research universities have always supported prestigious professional schools, but the prestige of library schools declined with the rise of higher-paid IT and software engineering professions. Between 1978 and1995, 15 American library schools were shut down (Cronin, 1995, p. 45). Most of the survivors were rechristened Library and Information Science. The GLS

humanities orientation had given way, librarianship was being changed by technology. New curricula and faculty with different skills were needed.

The changes did not go smoothly or as anticipated. Forced multidisciplinarity is never easy. Exclusion of technology studies may have been a reasonable reaction to the expense and limitations of new technologies. However, Moore's Law lowered the costs and removed many of the limitations with a speed that left little time to prepare. Young information scientists were not interested in absorbing a century of work on indexing, classifying, and providing access to complex information repositories; their eyes were fixed on a future in which many past lessons would not apply—and those that still applied would likely have to be relearned. The conflicts are exposed in a landmark 1983 collection, *The study of information: Interdisciplinary messages* (Machlup and Mansfield, 1983). In the book, W. Boyd Rayward described the outlined the traditional and technological perspectives and argued that there had been convergence. His essay is followed by commentaries attacking him from both sides.

In a series of meetings beginning in 1988, new deans at Pittsburgh, Syracuse, Drexel, and subsequently Rutgers discussed approaches to explaining and managing multidisciplinary schools. Despite this progressive effort, Cronin (1995) depicted the library and information science camps at loggerheads and in a "deep professional malaise." He suggested that librarianship be cut loose in favor of stronger ties to cognitive and computer science. Through the 1990s, several universities dropped "Library," becoming schools of Information (see Figure 2). More would follow.
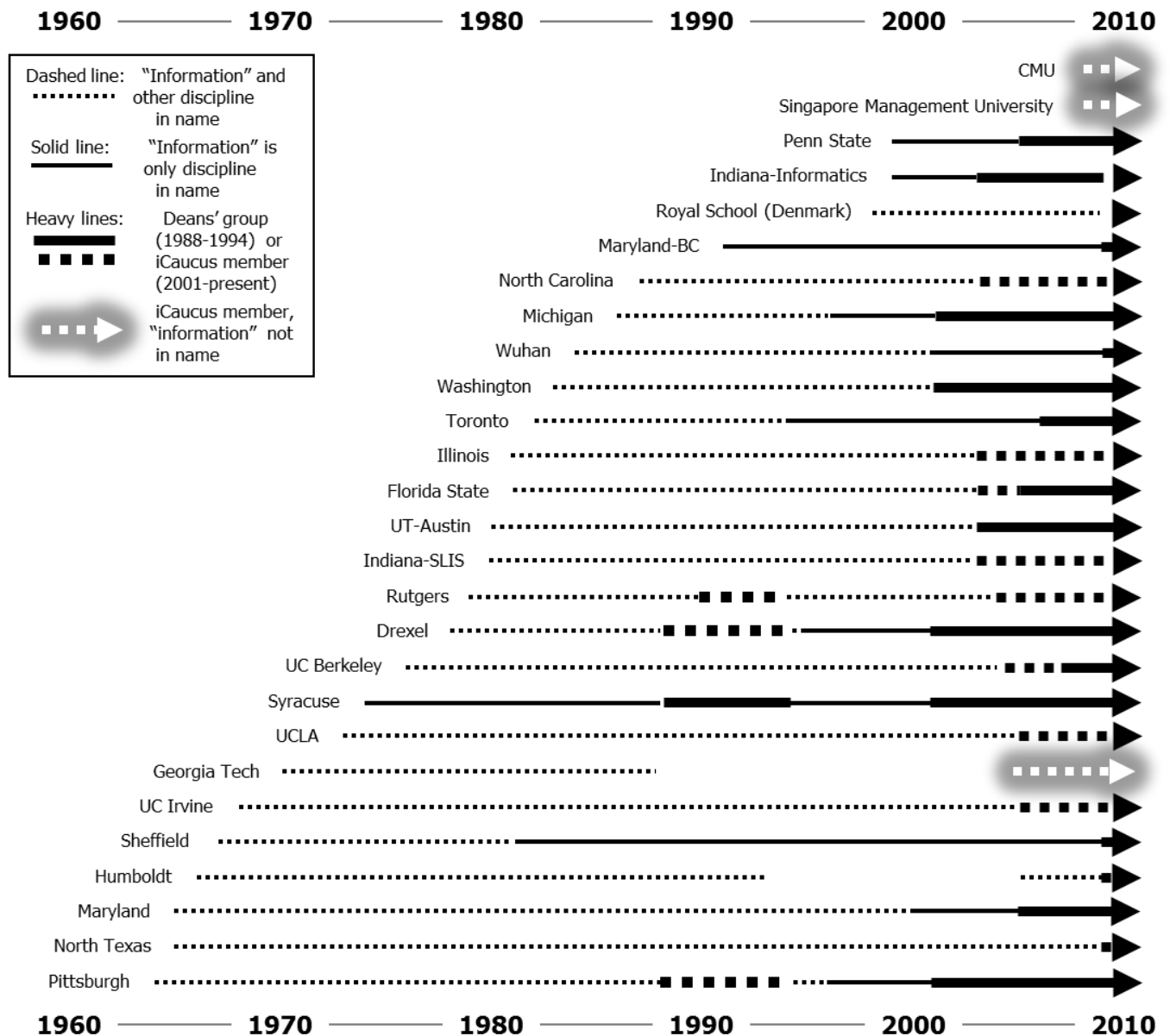


**Figure 2. The iCaucus and when "information" came into their names.**

How did the spread of the Internet and the emergence of the Web affect HCI research threads? CHI researchers were Internet-savvy. Although excited by the prospects, they took these changes in stride. Over time, CHI-related research, development, and use evolved. The Internet and Web were not disruptive to Human Factors and Ergonomics, either. The Web was initially a return to a form-driven interface style, and it was rarely a locus of routine work anyway. However, the Web had a seismic impact on Information Systems and on Information Science, so this section begins with them.

### The Formation of AIS SIGHCI

Computer users in organizations were no longer focused on maximizing computer use—everywhere, screen savers had become the main consumer of processor cycles. Embrace of the Internet created more porous organizational boundaries. Employees often download free software such as instant messaging clients, music players, and weblog tools inside the firewall despite IT concerns about productivity and security. These are not the high-overhead applications of the past. Increasingly, software can be used from a web browser without any download--Facebook, Twitter, and myriad other applications and services. Experience with web sites, downloads, and consumer used at home, left employees impatient with poor software at work. In addition, many managers who had been hands-off users became late adopters in the late 1990s or were replaced by younger managers. Managers and executives are now hands-on early adopters of some technologies.

Significant as these changes are for information systems in organizations, the Web had a more dramatic effect to deliver. Corporate IT groups had always focused on internal operations. They lived inside the firewall, their customers were other employees. Suddenly, organizations were scrambling to create Web interfaces to external vendors and customers. Discretionary users! After the Internet bubble burst, revealing that IT professionals, IS experts, and everyone else had limited understanding of these phenomena, on-line marketing, services, and business-to-business systems continued to grow. For many, the Web had become an essential business tool. In handling external customers, IT pros and IS researchers were in much the same place CHI was 20 years earlier, whether they realized it or (most often) not.

In 2001, the Association for Information Systems (AIS) established the Special Interest Group in Human–Computer Interaction (SIGHCI). The founders defined HCI by citing 12 CHI research papers (Zhang et al., 2004, p. 148). Bridging to the CHI and the Information Science communities was declared a priority (Zhang, 2004). SIGHCI's charter includes a broad range of organizational issues, but the published work emphasizes interface design for e-commerce, online shopping, online behavior "especially in the Internet era" (p. 1), and effects of Web-based interfaces on attitudes and perceptions. Eight of the first ten papers in SIGHCI-sponsored journal issues covered Internet and Web behavior.

In 2009, *AIS Transactions on Human Computer Interaction* was launched. The shift from an organizational focus to the web and broader end-user computing is documented in Zhang et al.'s (2009) analysis of the IS literature from 1990 to 2008. By not listing CHI among related fields, this article indicated that the bridging effort had foundered, as had previous efforts between CHI and Human Factors, Office Information Systems, and IS within CSCW.

### Digital Libraries and the Evolution of LIS

By 1995, an Information wave had swept through the university system (Figure 2). Digital technology was in the LIS curriculum. Familiarity with technology use was a prerequisite for librarianship. Innovative research had not kept pace with professional training, however (Cronin, 1995).

The Internet grew exponentially, but in 1995 it was still a niche activity found mainly on campuses. In the mid-1990s, Gopher, a convenient system for downloading files over the Internet, attracted attention as a possible springboard for indexing distributed materials. Wells's (1938) "world brain" seemed within reach. Then the Web hit, transforming information acquisition, management, and access at an accelerating pace. Between 1994 and 1999, two NSF/DARPA/NASA/National Library of Medicine/Library of Congress/National Endowment for the Humanities/FBI initiatives awarded close to $200M for Digital Libraries research and development. This and other investments galvanized the research community.

By 2000, ten Schools (or equivalent units) had Information as the sole discipline in their name; today it is twice that. In 2001, a series of 'Deans meetings' began, modeled on those of the late 1980s. Original members Syracuse, Pittsburgh, and Drexel were joined by Michigan, Berkeley, and the University of Washington. All are now Information Schools. In 2005, the first annual 'IConference' drew participants from nineteen universities that had Information programs. As of 2010, the 'iCaucus' has 27 dues-paying members. Some are transformed library schools, some had closer ties to other disciplines, or formed recently as a school of Information. Collectively, their faculty include HCI researchers trained in all four disciplines discussed here: HF&E, IS, CHI, and Information.

Expansion is not without growing pains. Conflicts arise among academic subcultures. The iConference competes with more established conferences in each field. Figure 2 suggests that a shift to a field called Information is well underway, but

many faculty still consider themselves "a researcher in {X} who is located in an Information School," where X could be Library Science, HCI, CSCW, IS, Communication, Education, Computer Science, or others. We don't know how it will evolve, but we can say with confidence that Information has become, and will remain, a significant player in human-computer interaction.

## HF&E Embraces Cognitive Approaches

In 1996, the Human Factors and Ergonomics Society formed a new technical group, Cognitive Engineering and Decision Making. It quickly became the largest technical group. A decade earlier this would have been unthinkable: Some leading HF researchers disliked cognitive approaches. The CHI community first used 'cognitive engineering' in this sense (Norman, 1982; 1986). As this development suggests, the Computer Systems Technical Group declined in size and prominence as HCI dispersed. Most HF&E technical groups, from telecommunications to medical systems, address digital technology and thereby HCI-related research.

Equally astonishing, in 2005 Human Performance Modeling was a new and thriving HFES technical group, initiated by Wayne Gray and Dick Pew, who had been active in CHI in the 1980s. Card, Moran, and Newell (1983) had introduced human performance modeling to reform the discipline of Human Factors from without. Work continued within CHI, focused on expert performance (e.g., a special issue of *Human-Computer Interaction,* Vol. 12, Number 4, 1997). Today the reform effort has moved within Human Factors, still focused largely on non-discretionary use.

Government funding of HCI was to a large degree shaped by HF&E. The Interactive Systems Program of the U.S. National Science Foundation—subsequently renamed Human–Computer Interaction—was described this way:

The Interactive Systems Program considers scientific and engineering research oriented toward the enhancement of human-computer communications and interactions in all modalities. These modalities include speech/language, sound, images and, in general, any single or multiple, sequential, or concurrent, human-computer input, output, or action." (National Science Foundation, 1993)

One NSF program manager identified his proudest accomplishment: doubling the already ample funding for natural language understanding. Even after NSF established a separate Human Language and Communication Program in 2003, speech and language research was heavily supported by both the HCI and Accessibility programs, with lighter support from AI and other programs. Subsequent NSF HCI program managers emphasized 'direct brain interfaces' or 'brain-computer interaction,' based on brainwaves and implants. NSF program managers rarely attended CHI conferences, which had little on speech, language, or direct brain interaction. These technologies may prove useful, but they will not appear soon in discretionary use situations in homes and offices. A review committee noted that a random sample of NSF HCI grants included none by prominent CHI researchers (National Science Foundation, 2003).

## CHI Evolves, Embraces Design

The steady flow of new hardware, software features, applications, and systems insures that people are always encountering and adopting digital technologies for the first time. This is important to technology producers, and it generates new research issues. CHI has tracked this flow, generally focusing on an innovation when it first starts to attract a wide audience.

As an application matures, use often becomes routine. Technologies such as email and word processing, no longer discretionary for most of us, get less attention from CHI, where the gaze is directed to the discretionary use of the moment: web design, ubiquitous and mobile computing, social computing, Wikipedia use, and so on. New technologies raised new issues, such as information overload, privacy, and effects of multitasking, and encouraged new methods, such as ethnography and data mining. At a higher level, continuity can be found in CHI: exploration of input devices, communication channels, information visualization techniques, and design methods. Proposals to build HCI theory on these shifting sands (Barnard et al., 2000; Carroll, 2003) remain largely aspirational.

Expanding participation in an Internet that steadily became more reliable and higher bandwidth through the mid-1990s increased the focus on real-time and quasi-real-time communication technologies such as email. The Web temporarily slowed this by shifting attention to indirect interaction with static sites, but with Web 2.0 and spreading support for animation and video, the pace quickened. The Web was like a new continent. Explorers posted flags here and there. Then came attempts at settlement, with virtual worlds research and development in the late 1990s. Few of the early pioneers survived; there was little to do in virtual worlds other than chat and play games. But slowly some people shifted major portions of their work and play online, relying on online information sources, digital photo management, social software, digital documents, online shopping, multiplayer games, and so on. This evolution is reflected in CHI research.

The Web curtailed research into powerful, self-contained personal productivity tools. To represent knowledge in application software had high development and maintenance costs, but when access to external information resources was limited, it was appealing. With a flood of information and access to knowledgeable people online, static knowledge representation is less useful. In contrast, adaptive systems that merge and filter local and Internet-based information have a role. Steady pro-

gress in machine learning is influencing productivity tools—although implausible AI forecasts have not disappeared.

To the psychologists and computer scientists who formed CHI, interface design was a matter of science and engineering. They focused on performance and assumed that people eventually choose efficient alternatives. Because human discretion involves aesthetic preferences and invites marketing and non-rational persuasion, this view was not sustained when computing costs came down. An engineering orientation gripped CHI longer than SIGGRAPH, where aesthetic appeal motivated much research. CHI researchers eventually came around, but labeled the study of enjoyment "funology" (Blythe et al., 2003), lest someone think that they were having too much fun.

Some visual designers participated in graphical interface research early on. Aaron Marcus began working full time on computer graphics in the late 1960s. William Bowman's 1968 book Graphic Communication was a strong influence on the Xerox Star, for which the designer Norm Cox's icons were chosen (Bewley et al., 1983). However, graphic design was considered a secondary activity (Evenson, 2005). In 1995, building on working group meetings at previous conferences, SIGCHI initiated Designing Interactive Systems (DIS), a biennial conference drawing more systems than visual designers. In 2003, SIGCHI, SIGGRAPH, and the American Institute of Graphic Arts (AIGA) initiated the Designing for User Experience (DUX) conference series that fully embraced visual and commercial design. This effort lasted only through 2007, but the shift was broad. Design is not assessed in research papers, but the changing sensibility is reflected in *ACM Interactions*, a magazine launched by CHI in 1994, which has steadily increased the focus on design, in both its content and its appearance.

Design's first cousin, Marketing, has been poorly regarded by the CHI community (Marcus, 2004). However, website design forces the issue. Site owners wish to keep users on a site, whereas users may prefer to escape quickly. Consider supermarkets, which position items that most shoppers want far apart, forcing people to traverse aisles where other products beckon. CHI professionals usually align themselves with 'end users,' but when designing for a site owner, they face a stakeholder conflict. This was not true in the past: Designers of individual productivity tools had negligible conflict of interest with prospective customers. Concerned with identifying and satisfying user needs, Marketing will likely find a place in CHI (perhaps labeled 'brandology').

Finally, CHI has become more open to work with a mild social or political stance. Accessibility was first addressed in the context of physical constraints. Socioeconomic factors were included in conferences on Universal Usability in 2000 and 2003. Support for sustainability and fitness emerged as topics. This shift may reflect a distancing from a sense that engineering should strive for value neutrality, a bid for relevance by an increasingly academic group, or aging CHI baby boomers who are considering their legacies.

The evolution of CHI is reflected in the influential contributions of Donald Norman. A cognitive scientist who introduced the term cognitive engineering, he presented the first CHI 83 paper. it defined 'User Satisfaction Functions' based on speed of use, ease of learning, required knowledge, and errors. His influential 1988 book Psychology of Everyday Things (POET) focused on pragmatic usability. Its 1990 reissue as Design of Everyday Things reflected a field refocusing on invention. Fourteen years later he published Emotional Design: Why We Love (or Hate) Everyday Things, stressing the role of aesthetics in our response to objects.

## LOOKING BACK: CULTURES AND BRIDGES

Despite overlapping interests, in a dynamic environment with shifting alliances, the major threads of human-computer interaction research—human factors and ergonomics, Information Systems, Library and Information Science, and Computer-Human Interaction have not merged. They have interacted remarkably little, although not for lack of effort to build bridges. The Human Factors Society co-organized the first CHI conference. CSCW sought to link CHI and IS. Mergers of OIS with CHI and later CSCW were considered. AIS SIGHCI tried to engage with CHI. LIS researchers interested in technology use have been active as individuals in activities in the other fields.

Even within Computer Science, bridging proved difficult. Researchers interested in interaction left SIGGRAPH to join CHI rather than form a bridge. A second opportunity arose 20 years later when standard platforms were powerful enough for photorealism to be a possibility. But the DUX conference series was discontinued after three meetings. In AI, SIGART and SIGCHI cosponsor the Intelligent User Interface series, but participation has remained outside mainstream HCI. What have been the obstacles to more extensive interaction across fields?

### Discretion Is a Major Differentiator

HF&E and IS arose before discretionary hands-on use was common. The Information field only slowly distanced itself from supporting specialists. CHI occupied a new niche: discretionary use by non-experts. HF&E and especially IS researchers considered organizational factors; CHI with few exceptions avoided domain-dependent work. As a consequence, HF&E and IS researchers shared journals. For example, Benbasat and Dexter (1985) was published in *Management Science* and cit-

ed five *Human Factors* articles. Apart from Information, all moved quickly to focus on broad populations, IS countering its organizational focus by insisting that work be framed by theory.

The appropriateness of a research method is tied to the motivation of prospective users. HF&E and CHI were shaped by psychologists trained in experimental testing of hypotheses about behavior, and hypothesis-driven experimentation was also embraced by IS. Experimental subjects agree to follow instructions for an extrinsic reward. This is a reasonable model for nondiscretionary use, but not for discretionary use. CHI researchers relabeled subjects 'participants,' which sounds volitional, but found that formal experimental studies were usually inappropriate: too many variables to test formally and feedback from a few participants was often enough. And because of the motivational issues, lab studies of initial or casual use required confirmation in real-world settings anyway, more so than studies of expert or trained behavior.

The same goals apply—fewer errors, faster performance, quicker learning, greater memorability, and being enjoyable—but the emphasis differs. For power plant operation, error reduction is key, performance enhancement is good, and other goals are less critical. For telephone order entry takers, performance is critical, and testing an interface that could shave a few seconds from a repetitive operation requires a formal experiment. In contrast, consumers often respond to visceral appeal and initial experience. In assessing designs for mass markets, avoiding obvious problems can be more important than striving for an optimal solution. Less-rigorous discount usability or cognitive walkthrough methods (Nielsen, 1989; Lewis et al., 1990), can be enough. Relatively time-consuming qualitative approaches, such as contextual design or persona use (Beyer and Holtzblatt, 1998; Pruitt and Adlin, 2006), can provide a deeper understanding when context is critical or new circumstances arise.

CHI largely abandoned its roots in scientific theory and engineering, which did not impress researchers from HF&E or theory-oriented IS. The controversial psychological method of verbal reports, developed by Newell and Simon (1972) and foreshadowed by gestalt psychology, was applied to design by Clayton Lewis as 'thinking-aloud' (Lewis and Mack, 1982; Lewis, 1983). Perhaps the most widely used CHI method, it led some in the other fields to characterize CHI people as wanting to talk about their experiences instead of doing research.

## Academic, Linguistic, and Generational Cultures

The academic culture of the sciences is that conferences are venues for work in progress and journals are repositories for polished work. HF&E, IS, Documentation, and Library Science followed this practice. In contrast, U.S. Computer Science disciplines shifted to conference proceedings as the final destination of most work. Outside the United States, Computer Science retained a journal focus, which suggests that the determining factor was the presence in the U.S. of professional societies, ACM and IEEE, that archive conference proceedings (Grudin, 2010). Information Science draws on researchers from each camp. A difference in preferred venue impedes communication. Researchers in journal cultures chafe at CHI's insistence on polish and its rejection rates; CHI researchers are dismayed by the lack of polish at other conferences.

CHI conferences accept only about 20% of submissions. With a few exceptions, HF&E and IS conferences accept about 50% or more. In contrast, CHI journals receive fewer submissions and have higher acceptance rates. Many CHI researchers report that journals are not relevant. I estimate that at most 15% percent of the work in CHI-sponsored conferences reaches journal publication. In contrast, an IS track organizer for HICSS estimated that 80 percent of research there progressed to a journal (Jay Nunamaker, opening remarks at HICSS-38, January 2004).

A linguistic divide also set CHI apart. HF&E and IS used the term 'operator' and a user could be a manager who read printed reports. For CHI, 'operator' was demeaning and a user was always hands-on. In HF&E and IS, 'task analysis' refers to an organizational decomposition of work, perhaps considering external factors; in CHI 'task analysis' is a cognitive decomposition, such as breaking a text editing move operation into select, cut, select, paste. In IS, 'implementation' meant organizational deployment; in CHI it was a synonym for development. System, application, and evaluation also had different connotations or denotations. Significant misunderstandings resulted from failure to understand linguistic differences.

Different perspectives and priorities were also reflected in attitudes toward standards. Many HF&E researchers contributed to standards development, believing that standards contribute to efficiency and innovation. A view widespread in CHI was that standards inhibit innovation. Both views have elements of truth, and positions partly converged as Internet and Web standards were tackled. However, the attitudes reflected the different demands of government contracting and commercial software development. Specifying adherence to standards is a useful tool for those preparing requests for proposals, whereas compliance with standards can make it more difficult for a product to differentiate itself.

As noted earlier, a generational divide also existed. Many CHI researchers who grew up in the 1960s and 1970s did not appreciate the prior generation's orientation toward military, government, and business systems. They are also put off by the lack of gender neutrality in the HF&E and IS 'man-machine interaction' literature, a difference one still sometimes sees. Only in 1994 did *International Journal of Man-Machine Studies* become *International Journal of Human-Computer Studies.* Such differences affected enthusiasm for building bridges and exploring literatures.

Competition for resources was another factor. Computers of modest capability were extremely expensive for much of the time span we are considering. CHI was initially largely driven by the healthy tech industry, the other fields were more dependent on government funding that waxed and waned. When funding waxed, demand for researchers outstripped supply. HCI prospered in AI winters, starting with Sutherland's use of the TX-2 when AI suffered its first setback and recurring with

the emergence of major HCI labs during the severe AI winter of the late 70s. Library Schools laboring to create Information Science programs had to compete with Computer Science departments that awarded faculty positions to graduate of Masters programs when supply was shortest.

Greater interdisciplinarity is intellectually seductive. Couldn't more be learned by looking over fences? But a better metaphor might be the Big Bang. Digital technology is an explosion, streaming matter and energy in every direction, forming worlds that at some later date might discover one another and find ways to communicate, and might not.

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## LOOKING FORWARD: TRAJECTORIES

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The future of HCI will be varied, dynamic, and full of surprises. The supralinear growth of hardware capability confounds efforts at prediction: We rarely experience exponential change of this kind and do not reason well about it. In the U.S., the National Science Foundation is tasked with envisioning the future and providing resources for moving us there, yet two major recent HCI initiatives, 'Science of Design' and creativity ('CreativIT'), wound down quickly, joining heavily-backed, quixotic efforts such as the decades of funding for speech and language. In this section, I extrapolate from observations about the past and present to suggest possible developments, as a prism through which to view other handbook chapters and perhaps as modest guidance in planning a career.

### Discretion—Now You See It, Now You Don't

We exercise prerogative when we use digital technology, sometimes. More often when at home, less often at work. Sometimes we have no choice, as when confronted by a telephone answering system. Those who are young and healthy have more choices than those constrained by injury or aging.

Software that was discretionary yesterday is indispensable today. Collaboration forces shared conventions. Consider a hypothetical team that has worked together for 20 years. In 1990, members exchanged printed documents. One person still used a typewriter, others used different word processors. One emphasized words by underlining, another by italicizing, a third by bolding. In 2000, the group decided to collaborate on documents digitally. They had to adopt the same word processor. Choice was curtailed; it was only exercised collectively. Today, the team is happy sharing documents in PDF format, so they can again use different word processors. Perhaps tomorrow software will let them personalize their view of a single underlying document, so one person can again use and see in italics what another sees as bold or underlined.

Shackel (1997, p. 981) noted this progression under the heading "From Systems Design to Interface Usability and Back Again." Early designers focused at the system level; operators had to cope. When the PC merged the roles of operator, output user, and program provider, the focus shifted to the human interface and choice. Then individual users again became components in fully networked organizational systems. Discretion can evaporate when a technology becomes mission-critical, as word processing did, and email in many places by the end of the 1990s.

The converse also occurs. Discretion increases when employees can download free software, bring smartphones to work, and demand capabilities that they enjoy at home. Managers are less likely to mandate the use of a technology that they use and find burdensome. For example, language processing systems appealed to military officers—until they themselves became hands-on users:

Our military users . . . generally flatly refuse to use any system that requires speech recognition. . . . Over and over and over again, we were told 'If we have to use speech, we will not take it. I don't even want to waste my time talking to you if it requires speech. . . .' I have seen generals come out of using, trying to use one of the speech-enabled systems looking really whipped. One really sad puppy, he said 'OK, what's your system like, do I have to use speech?' He looked at me plaintively. And when I said 'No,' his face lit up, and he got so happy." (Forbus, 2003; see also Forbus, Usher & Chapman, et al., 2003.)

As more applications become essential and security concerns curtail openness, discretion could recede. But Moore's Law (broadly construed), competition, and the ease of sharing bits should guarantee a steady flow of experimental technologies with unanticipated and thus discretionary uses.

### Ubiquitous Computing, Invisible HCI?

Norman (1988, p. 185) wrote of "the invisible computer of the future." Like motors, he speculated, computers would be present everywhere and visible nowhere. We interact with clocks, refrigerators, and cars. Each has a motor, but who studies

human–motor interaction? A decade later, at the height of the Y2K crisis and the Internet bubble, computers were more visible than ever. But after a quarter century, while we may always want a large display or two, would anyone call a smartphone or book reader a computer? Norman's vision may be materializing.

With digital technology embedded everywhere, concern with interaction is everywhere. HCI may become invisible through omnipresence. And as interaction with digital technology becomes part of everyone's research, the three long-standing HCI fields are losing participation.

*Human Factors and Ergonomics.* David Meister, author of *The History of Human Factors and Ergonomics* (1999), stresses the continuity of HF&E in the face of technology change:

Outside of a few significant events, like the organization of HFS in 1957 or the publication of Proceedings of the annual meetings in 1972, there are no seminal occurrences . . . no sharp discontinuities that are memorable. A scientific discipline like HF has only an intellectual history; one would hope to find major paradigm changes in orientation toward our human performance phenomena, but there is none, largely because the emergence of HF did not involve major changes from pre-World War II applied psychology. In an intellectual history, one has to look for major changes in thinking, and I have not been able to discover any in HF. (e-mail, 7 September 2004)

Membership in the Computer Systems Technical Group has declined. Technology is heavily stressed in technical groups such as Cognitive Engineering and Decision Making, Communication, Human Performance Modeling, Internet, System Development, and Virtual Environment. Nor do Aging, Medical Systems, or other groups avoid 'invisible computers.'

*Information Systems.* As IS thrived during the Y2K crisis and Internet bubble, other management disciplines—finance, marketing, operations research, organizational behavior—become more technically savvy. When the bubble burst and enrollments declined, the IS niche was less well-defined. The research issues remain significant, but this cuts two ways. As IT organizations standardize on products and outsource IT functions, business-to-business and web portals for customers get more attention. These have economic and marketing elements, with the risk that HCI functions will be outsourced to other management disciplines.

*Computer-Human Interaction.* This nomadic group started in psychology, then won a seat at the Computer Science table, bestowed grudgingly. Several senior CHI people moved into Information schools and programs. Lacking a well-defined academic niche, CHI ties its identity to the SIGCHI organization and the CHI conference. SIGCHI membership peaked in 1992, conference attendance peaked in 2001. As technologies appear at an ever-increasing pace, thriving specialized conferences are started, often by younger researchers. World Wide Web conferences included papers on HCI issues from the outset. HCI is an 'invisible' presence in conferences on agents, design, and ubiquitous, pervasive, accessible, social and sustainable computing. High rejection rates for conference submissions and a new generational divide could accelerate the dispersion of effort.

CHI membership has become more exclusively academic, whereas industry has a growing need for basic research in different domains. Apart from educational and medical settings, which have broad appeal, CHI remains largely focused on general phenomena and resistant to domain-specific work. This too presents opportunities for regional and specialized conferences.

## Information

Early in the computer era, there were no networks and memory was fantastically expensive. Computers were for computation, not information processing. Today, the situation is reversed: memory and bandwidth are so plentiful that most computation is in the service of processing and distributing information. And this is likely to accelerate.

Cronin (2005) proposed that access, in terms of intellectual, physical, social, economic, and spatial/temporal factors, is the focus of the information field. Information is acquired from sensors and human input, it flows over networks including the Web, is aggregated, organized, and transformed. The routing and management of information within enterprises, and the consequences of ever more permeable organizational boundaries, is evolving before coming into research focus. Personal information management is also rapidly changing. Once centered on shoeboxes of photographs and boxes of old papers, now each of us faces significant online information management, choosing what to keep locally, what to maintain in the cloud, and how to organize it and insure its future accessibility. CHI has over a decade of work on information design or visualization (see the Information Visualization chapter by Stuart Card).

In speculating about the future, Cronin (2005, p. 56) quotes Wersig (1992) who argued that concepts around information might function "like magnets or attractors, sucking the focus-oriented materials out of the disciplines and restructuring them within the information scientific framework." Could this happen? Information Schools have hired senior and junior people from all relevant areas. Andrew Dillon, Dean of the University of Texas School of Information, worked at Loughborough with Brian Shackel and Ken Eason. Syracuse, the first extant school of Information in 1974, has faculty with IS training and orientation.

CHI faculty have migrated to Information schools and departments at several leading research universities.

Of course, the rise of specialized programs—biomedical informatics, social informatics, community informatics, information and communication technology for development (ICT4D)—presents a countervailing force. Information, like HCI, could become invisible through ubiquity. The annual Information Conference is a barometer. In 2005 and 2006, there was active discussion and disagreement about directions. Should new journals and research conferences be pursued, or stick with established venues in contributing disciplines? Faculty from different fields worked out pidgin languages to communicate with other. In the years since, many assistant professors were hired and graduate students enlisted. Their initial jobs and primary identities are with Information. Will they creolize the pidgin language?

Listening to the discussions, my sense is that the generals may still be arguing over directions, but the troops are starting to march. It is not clear where they will go. The annual conference is fragile; the generals are busy with local campaigns but reluctant to turn over command. In any case, in the long term, Information will be the major player in human-computer interaction. Design and Information are active HCI foci in 2010. Design activity is compensating for past neglect. Information is being reinvented.

# CONCLUSION: THE NEXT GENERATION

Until revoked, Moore's Law will ensure that digital landscapes provide new forms of interaction to explore and new practices to improve. The first generation of computer researchers, designers, and users grew up without computers. The generation that followed used computers as students, entered workplaces, and changed the way technology was used. Now a generation has grown up with computers, game consoles, and cell phones. They absorbed an aesthetic of technology design, while communicating with IM and text messaging. They are developing skills at searching, browsing, assessing, and synthesizing information. They use digital cameras and blog, acquire multimedia authoring talent and embrace social networking sites. They have different takes on privacy and multitasking. They are entering workplaces, and everything will be changed once again. However it is defined and wherever it is studied, human–computer interaction will for some time be in its early days.

# APPENDIX: PERSONAL OBSERVATIONS

My career from 1973 to 1993 followed a common enough path. I was one of many who worked as a computer programmer, studied cognitive psychology, spent time as an HCI professional in industry, then moved to academia. I describe some personal experiences below not because I was special, but to add texture and a sense of the human impact of some of the developments I have described. My interest in history arose from the feeling of being swept along by invisible forces, sometimes against my intention. My first effort at understanding was titled "The Computer Reaches Out" (Grudin, 1990)—I saw computers evolving and slowly reaching into the world and changing it in ways that we, their developers, had not foreseen.

*1970: A Change in Plans.* As a student, I read and believed the Life magazine article that forecast super-human intelligent computers arriving in several years. I concluded that if we survived a few years, we could count on machines to do all useful work. Humans should focus on what they enjoy. I shifted from physics to mathematics and from politics to literature.

*1973: Three Professions.* Looking for my first job in 1973, I found three computer job categories in the Boston Globe classifieds: operators, programmers, and systems analysts. Not qualified to be a highly paid analyst, I considered low-paid, hands-on operator jobs but landed a programming job with Wang Laboratories, at the time a small electronics company. For two years, I never saw the computer that my programs ran on. We flowcharted on paper and coded on coding sheets that a secretary sent to be punched and verified. A van carried the stack of cards 20 miles to a computer center, and later that day or the next I got the printout (e.g., "Error in Line 20") and resumed work on the program.

*1975: A Cadre of Discretionary Hand-On Users.* In 1975, Wang acquired a few teletype terminals with access to the WYLBUR line editor, developed at the Stanford Linear Accelerator. Some of us programmers chose to abandon paper and became hands-on computer users.

*1983: Chilly Reception for a Paper on Discretion in Use.* My first HCI publication, Grudin & MacLean (1984), was written when I was a postdoc at the MRC Applied Psychology Unit. Allan and I showed that people sometimes choose a slower in-

terface for aesthetic or other reasons even when they are familiar with a more efficient alternative. A senior colleague asked us not to publish it. He worked on improving expert efficiency through cognitive modeling. A demonstration that greater efficiency could be undesirable would be a distraction, he said: "Sometimes the larger enterprise is more important than a small study."

*1984: Encountering IS, Human Factors, and Design.* Upon returning to Wang, which had become a large minicomputer company, I was influenced by another cognitive psychologist, Susan Ehrlich. She was in a marketing research group and later managed the human factors group. She introduced me to the IS literature, which I found difficult to understand. I attended Boston-area chapter meetings of both the HFS and SIGCHI. I saw the cultural differences but felt CHI could learn from human factors. In a conscious-if-futile gesture to counter CHI antipathy toward human factors, I began calling myself a human factors engineer. I drove to Cambridge to see the newly released Macintosh. Few software engineers had the visual design skills that I realized would become important, so at work I looked for industrial designers of hardware ('boxes') who could be enlisted to support software interface design.

*1985: The GUI Shock.* In the early 1980s, I was one of many cognitive psychologists working on command naming. This was an important application in the era of command-line interfaces, but our ambition was to develop a comprehensive theoretical foundation for HCI. The success of the Mac in 1985 curtailed interest in command names. No one would build on our past work—a depressing thought. For most of us, it also dashed the hope of a comprehensive theoretical foundation for HCI. We had to choose: Am I a cognitive psychologist or a computer professional?

*1986: Beyond "The User": Groups and Organizations.* I agreed to join MCC, an industry research consortium. Between jobs I worked on two papers, each addressing a different major challenge encountered in product development. (i) From 1984 to 1986, I had worked on several products or features intended to support groups rather than individual users. These had not done well. Why was group support so challenging? (ii) It was painfully evident that organizational structures and development processes were badly suited to interactive software development. What could be done about it? These issues formed the basis of much of my subsequent research.

*1989: Development Contexts, a Major Differentiator.* I spent two years at Aarhus University. Within weeks of arriving in a country that had little commercial software development, I recognized the significance of the differences in the conditions that govern product, in-house, and contract development of interactive software, differences that shape CHI, IS, and software engineering perspectives. Sorting this out led to my first library research into historical information (Grudin, 1991). Perusing long-forgotten journals and magazines in dusty library corridors felt like wandering through an archaeological site.

*1990: Just Words: Terminology Can Matter.* I felt a premonition in 1987 when my IS-oriented colleague Susan Ehrlich titled a paper "Successful Implementation of Office Communication Systems." By implementation, she meant introduction into organizations. To me, implementation was a synonym for coding or development. Sure enough, the ACM editor asked her to change implementation to adoption (Ehrlich, 1987). What she called systems, I called applications. It left me uneasy. Was Language, usually an ally, getting in the way?

In 1990, I describe the focus of my planned HCI course at Aarhus as "user-interface evaluation." My new colleagues seemed embarrassed. Weeks later, a book written by one of them was published (Bødker, 1990). Its first sentence is a quotation: "Design is where the action is, not evaluation." Now I was embarrassed. In an in-house development world, with its dogma of getting the design right up front, development projects could take 10 years. Evaluation occurred at the end, when only cosmetic changes were possible—thus the negative stigma. In commercial product development, evaluation of the previous version, competitive products, and (ideally) prototypes was integral to design. Evaluation is central to iterative design, and draws on the skill experimental psychologists bring to the table. We considered it a good thing.

Later in 1990, I participated in a panel on task analysis at a European conference. To my dismay, this IS-oriented group defined task analysis differently than I did. To them, it meant an organizational task analysis: tasks as components in a broad work process. In CHI, it meant a cognitive task analysis: breaking a simple task into components; for example, is "move text" thought of as 'select-delete-paste' or 'select-move-place'? People became angry over perceived mis-use of the term.

Also in 1990, en route to give a job talk at UC Irvine, my first lecture to an IS audience at the UCLA Anderson School of Management ended badly when the department head asked a question. It seemed meaningless, so I replied cautiously. He rephrased the question. I rephrased my response. He started again, then stopped and shrugged as if to say, "this fellow is hopeless." When I saw him a few months later, he was visibly astonished to learn that his Irvine friends were hiring me. Later, I understood the basis of our failure to communicate: We attached different meanings to the word 'users.' In CHI, it meant hands-on computer users. IS users might never use a keyboard—they identified software requirements, managed development, read printed output and reports, and so on. His question had focused on users who were not hands-on. To me, all use was hands on, so the question made no sense.

A book could be written about the word 'user.' From a CHI perspective, the IS user was the 'customer.' Consultants use 'client.' In IS, the hands-on user was the 'end-user.' In CHI's parlance, 'end-user' and 'user' were one and the same—a per-

son who entered data and used the output—so 'end-user' seemed superfluous or an affectation. Human factors used 'operator,' which CHI considered demeaning. In software engineering, 'user' typically denoted a tool user, namely a software engineer.

Finally, use of the male generic. I avoided submitting to *International Journal of Man-Machine Studies* and turned down an invitation to speak at a 'man-machine' interaction event. I was keen on learning from other disciplines, but that was a linguistic bridge I usually avoided crossing. I generally consider words to be a necessary but uninteresting medium for conveying meaning, but such experiences led to an essay on some of these unintended consequences of language (Grudin, 1993).

*2010: Reflections on Bridging Efforts.* I have been a minor participant in efforts to find synergies between CHI and human factors, office information systems, information systems (in both CSCW and AIS SIGHCI), and Design. As a boomer, I experienced generational and cultural divides. Some of us avoided publishing in 'man-machine' conferences and journals, and many of my MCC colleagues joined the consortium to avoid 'Star Wars' military projects. We lived through disputes between cognitive psychologists and radical behaviorist or strictly perceptual-motor psychologists. I was one of many CHI researchers who shifted from journals to conferences as primary publication venue, and from hypothesis-driven experimentation to build-and-assess and qualitative field research.

Some differences fade over time, but others continue to impede communication. Conference reviewers are often irritated by acronyms used by authors from other fields. Writing a chapter for an IS-oriented book, my coauthor and I wrangled at great length with the editor over terminology (Palen & Grudin, 2002).

A final example: In this research, I reviewed the literature on TAM, the model of white-collar employee perceptions of technology that is heavily cited in IS but never in CHI. Twice, I unsuccessfully searched online for TAM references. On the third such occasion, I saw why: TAM stands for 'Technology Acceptance Model,' but I had typed in 'Technology Adoption Model.' Nondiscretionary acceptance vs. discretionary adoption: different biases led to different terminology, and confusion.

*2010: Predicting the Future.* The final section discusses the trajectory of HCI disciplines in the context of forces created by hardware change. I have other thoughts about these forces and where we are headed, but I'm aware of no detailed forecasts, including mine, that look good upon close inspection. Those interested in my thoughts can find some in the November, 2006 and January, 2007 issues of *ACM Interactions*, http://interactions.acm.org/content/archives.php.

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