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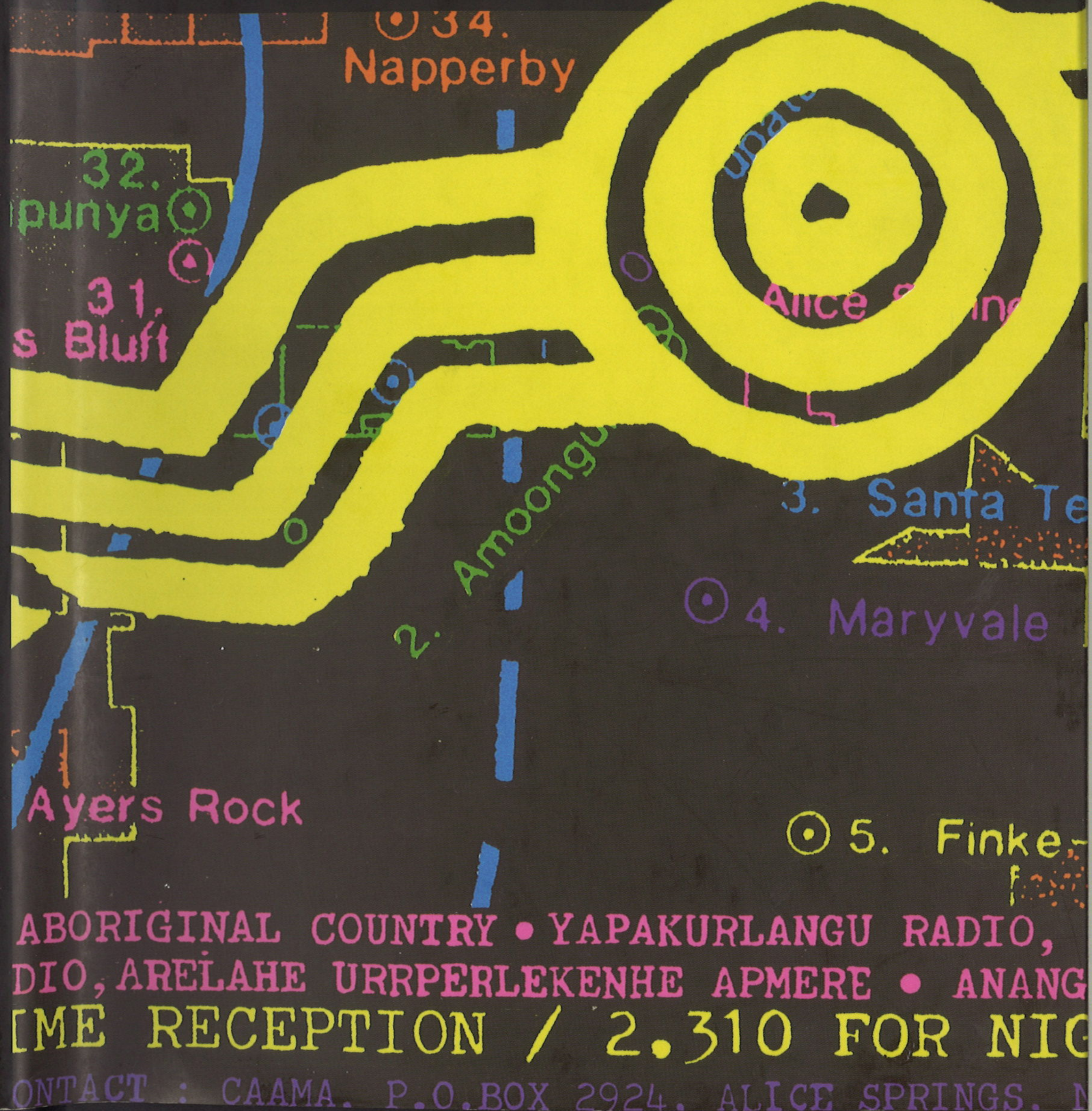
DIVINING A DIGITAL FUTURE DOURISH AND BELL

DIVINING A DIGITAL FUTURE

MESS AND MYTHOLOGY IN UBIQUITOUS COMPUTING

PAUL DOURISH AND GENEVIEVE BELL



McCullough, Christena Nippert-Eng, Eric Paulos, Yvonne Rogers, Christine Satchell, Phoebe Sengers, Brian Cantwell Smith, Lucy Suchman, Nina Wakeford, and Peter Wright.

At the outset of our collaboration, we found ourselves writing about infrastructure, and so we sent a draft of our first paper on the topic to Leigh Star, whose thinking and writing on infrastructure and messiness were as inspiring to us then as they are now. Leigh's generous and thoughtful engagements with us, around that paper and in the years that followed, were invaluable. Leigh passed away a few weeks before this manuscript was completed. Her presence is hugely missed both personally and intellectually.

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1 Introduction: The Myth and Mess of Ubiquitous Computing

> Ubiquitous computing names the third wave in computing, just now beginning. First were mainframes, each shared by lots of people. Now we are in the personal computing era, person and machine staring uneasily at each other across the desktop. Next comes ubiquitous computing, or the age of calm technology, when technology recedes into the background of our lives.
>
> —Mark Weiser, "The Computer for the 21st Century"

In Palo Alto, California, on Coyote Hill Road, in sight of the foothills of the coastal range, the Xerox Corporation runs a research and development center. Xerox founded its Palo Alto Research Center, or PARC as it is known, in 1970, and it has gone on to be a significant node in the cultural geography of Silicon Valley.[1] PARC is a leading research center and the site where, famously, a small group of researchers in the 1970s invented many of the elements of the contemporary personal computing environment—personal workstations with graphical user interfaces with overlapping windows, mice, local area networking, digital typography and document production, and more. PARC also helped create new stories about how technology would fit into the world; the personal computer, the graphic user interface, the paperless office, and ubiquitous computing are arguably the most enduring ones. The stories, or organizing visions, told in the pages of publications like the *New York Times* and *Scientific American*, were aimed at both technical and nontechnical audiences. For insiders, these visions created the opportunities for new research projects and publications; for the general public, they were something more. They prefaced new realities and new promises, and in so doing they echoed previous technology visions—the electrical age, the radio age, the television age, and even the atomic age.

1. After operating since 1970 as Xerox PARC, PARC was spun off as an independent but wholly owned subsidiary, PARC, Inc., in 2002.

Like those earlier technovisions, PARC's technotales would also become myths: they would create a way to make sense of the future that appeared simultaneously magically but also manageably. That these myths emanated from the center of Silicon Valley gave them a sense of inevitability as well. After all, if smart engineers and computer scientists say this is our future, then surely it will be true. This kind of rhetorical positioning also meant that to be skeptical of such visions was to be seen as against progress, a Luddite or worse. And like all good myths, there would be heroes, seemingly impossible tasks, perils, pitfalls, and dangers, and of course, in the end, glory.

In the late 1980s and early 1990s, a team of researchers at PARC, led by computer scientist Mark Weiser, found itself in a world shaped by two different yet increasingly convergent mythical stories. The team operated in a research culture framed by the "personal computer" story about the transformation of massive mainframe industrial computation machinery into something smaller, more intimate, and with the power to change human relations with technology and each other. It was also the first days of a new era, the "information age," also arguably mythical, where binary code would replace physical labor and information would trump mechanization as a driving economic force. Inhabiting a world very much bookended by these two stories—the personal computer and the information age—Weiser and his team, following early PARC researcher Alan Kay's injunction to predict the future by inventing it, staked their own claim in the technomythscape.

In talks, publications, and hallway conversations, a story about the next future of computation and also the next stage of the future of humanity emerged. This tale coalesced, in 1991, around the notion of ubiquitous computing (ubicomp)—a vision, as articulated by Weiser, that made sense of the information age while suggesting that personal computing had not gone far enough.

Weiser argued that the first era of computing had been that of mainframes—large, centralized computers used by hundreds or thousands of people. The second era, personal computing, was characterized by "a computer on everyday desktop," a world in which computational resources were deployed on a personal level. In the third era, ubiquitous computing, he contended that computational devices would be small and powerful enough to be worn, carried, or embedded in the world around us—in doors and tables, the fabric of clothes and buildings, and the objects of everyday life.

Computing technology, in this ubicomp vision, would be everywhere, anticipatory, and far more practical—it would be useful as well as

extraordinary. In this way, it was a familiar formulation—a technological breakthrough that would, when realized properly, change social relations, social order, and daily life, creating new possibilities, both commercial and culture. In the meantime, ubicomp was a useful organizing principle for industrial and academic research, conferences, journal articles, and papers along with prototypes, test beds, and experimentation. It has come to be broadly recognized in academic, commercial, and government settings worldwide as one of the key agendas for information technology research. And it has held sway, in a range of sites and guises, for more than twenty years. Influencing more than two generations of scholars, it has become a foundational story, a technomyth, in computer science and allied fields and as a result has shaped the kinds of technologies that have been made and also made possible.

Writing toward the end of the twentieth century, the pioneers in ubicomp research tried to anticipate the impacts and applications of their technologies decades into the future. That time, of course, is now, and many aspects of their vision have been realized, at least from a technological perspective. Weiser anticipated a world suffused with information technology, in which daily life might bring some people into contact with many, interconnected digital devices, large and small. For many people, in many parts of the world, this is indeed a fair characterization, but it only goes so far. Important considerations were unexamined or unexpected by the early researchers, from the widespread use of mobile communications technology in the developing world to the impact of location-based services on how Japanese teens interact, the emergence of new forms of political engagement online, or the need for legislation to curb our use of distracting devices while driving.

In this book, we examine the process of "divining a digital future." "Divining" has multiple meanings here. Most immediately, we consciously evoke the notion of divination—the complex and somewhat mystical process of inquiring into future events. We are struck, relatedly, by the link to the kinds of things that people do with divining rods—looking to uncover what lies hidden from immediate sight. At the same time, the notion of the divine—a search for transcendental phenomena, and a process by which some truths are found to lie beyond the realm of the mundane—is also implicated in the contemporary practice of conjuring technological futures. This is the broad landscape, but our particular attention is more locally to the domain of ubicomp in which we are both ourselves situated. Taking ubicomp to be at once a technological and an imaginative effort, we explore the vision that has driven the ubicomp research agenda and the contemporary practices that have emerged. Drawing on cross-cultural investigations of technology adoption, we argue for developing a "ubiquitous computing of the present" that takes the messiness of everyday life as a central theme.

Our goal is to understand the mythology of ubicomp. When we talk in terms of myths, we do not mean to suggest that ubicomp is somehow false or mistaken. We instead want to direct attention toward the ideas that animate and drive ubicomp forward, in much the same way that myths provide human cultures with ways of understanding the world and celebrating their values. As Vincent Mosco (2004, 3) notes:

> Useful as it is to recognize the lie in the myth, it is important to state at the outset that myths mean more than falsehoods or cons; indeed, they matter greatly. Myths are stories that animate individuals and societies by providing paths to transcendence that lift people out of the banality of everyday life. They offer an entrance to another reality; a reality once characterized by the promise of the sublime.

The myths we want to examine, then, are the stories that motivate and celebrate the development of the ubicomp agenda. They are the ideas that give it shape and meaning. They are ideas about what technology can do for people, the places it will go, and the needs it will address. While we might not often see technology in mythical terms, it is a useful strategy to uncover the ideas that shape our technological world—the ideas about human action that spurred early researchers in cybernetics and artificial intelligence (Hayles 1999; Pickering 2010), the cold war rhetoric that drove the development of digital computing (Williams 1996), the notions of politics and community that inflected the discourse of contemporary web technologies (Coyne 1999; Mosco 2004), or the visions of life and death at work in the artificial life community (Helmreich 1998).

Alongside the myth, there is the mess—the practical reality of ubicomp day to day. We do not use the term "mess" pejoratively; we rather like the mess (as anyone would be able to see who glanced at the space where we sit writing these words). When we talk of the mess, we want to suggest that the practice of any technology in the world is never quite as simple, straightforward, or idealized as it is imagined to be. For any of the infrastructures of daily life—the electricity system, the water system, telephony, digital networking, or the rest—the mess is never far away. Lift the cover, peer behind the panels, or look underneath the floor, and you will find a maze of cables, connectors, and infrastructural components, clips, clamps, and duct tape. Push further, and you will also encounter the regulatory authorities who authorize interventions and certify qualified individuals, committees that resolve conflicting demands in the process of setting standards, governments that set policy, bureaucrats who implement it, marketers who shape our views of the role of the infrastructure in our lives, and more. Mess is always nearby.

"Mess" refers, too, to the way that technological realities are always contested. No single idea holds about what technologies are and what they do. Though many have tried, attempts to reduce this complexity to a single reading are at best unsatisfactory; as Andrew Pickering (2010, 33) observes, "Ontological monotheism is not turning out to be a pretty sight." So partly our concerns with mess highlight not just an interest in "how things could have been different" but rather how they already are different among the different groups, places, contexts, and circuits that characterize contemporary ubicomp.

This book, then, is about ubicomp. It is about the stories that have been told, and all the stories that haven't been. It is about the research that has been done, and the research that should be done. It is about what computer science has been, at the intersection of daily life and computational technology, and what it could be. It is then a book about the myth of ubicomp and its messy reality and, by necessity, about the tensions between those two very different vantage points. As such, there are many things that this book is not. It is not an ethnographic account of the ubicomp community, though surely such an account is necessary. It is not a recitation of current ubicomp experiments and a reporting out of results; we leave that to other forums. It is also not an easy read or a quick fix for ubicomp. We are concerned instead with offering a thorough and rigorous critique. In so doing, we hope to open up ubicomp to a larger audience and to make room for a far more diverse set of practitioners, collaborators, and engagements.

As a project, a "ubiquitous computing of the present" would necessarily reach beyond computer science as a disciplinary foundation. Information technology is certainly a major component here, and indeed we find those projects that ignore the materiality and practical consequences of information technology as unsatisfying as those unable to see beyond it. In attempting to understand what ubicomp is today, however, we need to understand it not just technically but also culturally, socially, politically, and economically. Often, this means starting off by understanding it historically—understanding where it came from and what kinds of ideas and hopes contributed to its development. This will be our starting point here.

So at the same time, this project is something of an interdisciplinary experiment, and one fraught with not a little danger. As a socioculturally inclined computer scientist and a technologically inclined anthropologist, we have each always been oriented toward unconventional modes of analysis within our own disciplines. Working and writing together over the last few years, we have been able to join our voices with those of many others who have been working over many years, from different places and in different ways, to fashion a new disciplinary perspective on information technology and its workings in the world. Some amount of this project is thus a tentative exploration of alternate configurations of disciplinary and scholarly practice. A ubicomp of the present is both our topic and an exemplar of disciplinary hybridity that we find intriguing.

However, first things first: in this case it means ubicomp and its first stirrings in Palo Alto.

2 Contextualizing Ubiquitous Computing

"The most profound technologies," wrote Weiser (1991, 78) in the opening of his classic *Scientific American* article that laid the foundations for a research program in ubicomp, "are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it." Weiser was a computer scientist with wide-ranging interests. He had conducted significant research in programming systems, including advanced techniques such as program slicing and automated storage management ("garbage collection"), and was at the time director of the Computer Science Laboratory (CSL) at Xerox PARC. Weiser's influential article set out to provide the basis for a new paradigm and to document PARC's recent work in developing it. When Weiser explained that "my colleagues and I at the Xerox Palo Alto Research Center think that the idea of a 'personal' computer itself is misplaced," his words had especial salience, since these were the very people who had developed the idea of the personal computer in the first place.

The article is partly a manifesto and partly a progress report. As a manifesto, it follows in a long technological tradition (Brate 2002); it paints a picture of an alternative to the personal computing paradigm and extrapolates technological trends in order to present this alternative as both necessary and inevitable. As a progress report, it documents a range of contemporary research developments—primarily although not solely at PARC—that constitute steps along the path.

It is structured in several sections. Beginning with its resonant and widely quoted argument about technologies that "disappear," it suggests that a significant problem has arisen with the personal computing paradigm, which forces people to spend too much time "interacting with" their computers rather than using them to get things done. "The state of the art," Weiser remarks, "is perhaps analogous to the period when scribes had to know as much about making ink or baking clay as they did about writing."

The assertion that poorly designed computer systems have a tendency to get in the way and interfere with the tasks that people are trying to carry out was far from a new one; this, after all, was the central argument motivating research on human-computer interaction (HCI) and its efforts to focus attention on the user interface and experience. For social scientists Geoff Cooper and John Bowers (1995), in their essay on the disciplinary rhetorics of HCI, different formulations of this problem created the opportunity to wrest control of technological developments from computer scientists and create spaces where cognitive scientists and social scientists could bring their own expertise to bear. Weiser, however, takes a different tack—one that is fascinating with respect to interdisciplinary engagement. He makes two arguments simultaneously. First, he contends that the underlying problem is not simply one of the user interface but rather about the very conception of computational devices. This is an issue that will require significant engineering efforts and pose tremendous computer science challenges. Yet, at the same time, it is a problem that draws even more widely on other disciplines than HCI has traditionally done. Weiser invokes ecological psychologists and phenomenological philosophers as well as cognitive scientists and computer scientists in his attempts to reframe the problem. This is an engineering challenge, to be sure, he maintains, but it will not be business or research as usual.

In point of fact, Weiser's ubicomp was informed by a number of nontechnical impulses and sources. Ubicomp was in no small way a polemic about the perceived failure of the personal computer to deliver meaningful value to human beings. In a retrospective published eight years after the *Scientific American* article and just weeks after Weiser's death, John Seely Brown (then the chief technology officer of PARC) wrote: "We wanted to put computing back in its place, to reposition it into the environmental background, to concentrate on human-to-human interfaces and less on human-to-computer ones" (Weiser, Gold, and Brown 1999, 694). In the telling and retelling of the ubicomp story, discussions with colleagues at Xerox and beyond who were critical of the traditional conceptions of computation, interaction, and practice embedded in computer system design play an important part. Weiser and his colleagues shared the PARC facility with the Work Practice and Technology Group—a team led by anthropologist Suchman (1987, 1999, 2007; Blomberg, Suchman, and Trigg 1997) that took solid aim at issues of HCI, privileging the human side of the interaction while bringing a different set of methodological and theoretical impulses to PARC.

Writing of Suchman and her team, Weiser notes,

> To some of the technologists at PARC, myself included, their observations led toward thinking less about particular features of a computer—such as random access memory and number of pixels or megahertz—and much more about the detailed situational use of the technology. In particular, how were computers embedded within the complex social framework of daily activity, and how did they interplay with the rest of our densely woven physical environment (also known as "the real world")? (Weiser, Gold, and Brown 1999, 693)

In other words, sociological and ethnographic accounts of work practice and interaction had begun to suggest alternatives to traditional "cognitivist" accounts of interaction with computer systems and had emphasized the importance of looking at the systems of practice within which HCI was embedded (e.g., Orr 1996; Suchman 1999, 2007; Weiser, Gold, and Brown 1999). If the technical trends that Weiser examined looked to a day when computation could move "off the desktop," these alternative models of HCI suggested that this was also where the orderliness and "calm" of interaction was to be located as well as achieved (Weiser and Brown 1997). While our contemporary computational lives might scarcely be described as calm or even orderly (Rogers 2006), we might nonetheless conclude that in a world of cell phones, wireless computer networks, MP3 players, digital cameras, social networking websites, and virtual worlds, Weiser shrewdly anticipated technological trends.

The vision that Weiser laid out in 1991 replaced the traditional personal computer, desktop, or laptop with a range of small computational devices distributed through the everyday world and embedded into it. These devices operate at different scales. Weiser analogized them to different elements of the traditional office environment—devices on the scale of sticky notes, pads of paper, and whiteboards—connected via wireless networking technologies so that they can communicate and interoperate. In his approach, the computational experience moved away from the desktop and into the everyday world and was distributed across a range of devices, each specialized to particular sorts of tasks.

After outlining the overall vision, Weiser's article then moves on to report progress to date. As Weiser sets out the components of his ubicomp environment, he also presents the prototype systems developed by his colleagues at Xerox PARC, describing both their design and early experiences of their use. The effect of this portrayal is twofold. First, it shows the reality of the vision; no scientific pipe dream, Weiser's account of an alternative to the desktop computing paradigm is already becoming reality, as the lavishly illustrated article demonstrates. Second and relatedly, it begins to shape an argument for the future of ubicomp as inevitable; it is already on its way, delivered by the people who brought you the personal computer.

There is one further crucial resonance in the way that the progress report is provided. When the personal computing vision was emerging at PARC in the early 1970s, one of the laboratory's strategies was to develop and widely deploy its technologies within its own environment, and to live with and use them daily. PARC researcher Kay is famous for his observation that the best way to predict the future is to invent it; a corollary is that the best way to understand the future is to do your best to create a local approximation and try to use it day to day. Much of Xerox's success in developing its vision of personal computing had come from the researchers' ability to engage in this form of time-machine research. Weiser's article detailed the way that researchers were doing this once more. So while ubicomp constituted a break from the past, the research tools and strategies that would realize it would be those that had succeeded the last time around.

The inevitability of the new vision is further bolstered in the next section of his article, in which Weiser lays out trends in the development of key technologies. Here again, a familiar technological trope is deployed. In 1965, semiconductor engineer and Intel cofounder Gordon Moore first observed that the number of transistors that could be placed on a wafer of silicon had for several years been doubling every eighteen months. Moore did not formulate this as a prediction, but as it continued to hold over the next few years, others began to refer to it as "Moore's law," which came to be seen as a predictive model of technological development. Arguably, as it became widely accepted, it became somewhat self-fulfilling, as engineers addressed themselves to the problem of just how the next doubling in feature density might be achieved on schedule. In his article, Weiser invokes Moore's law to anticipate changes in computational power density and similarly extrapolates trends in storage and networking capacity. Weiser's predictions are reasonably accurate and even somewhat conservative. More interestingly, though, they further suggest the inevitability of his account; one has the sense that he is telling the reader, "This is coming, so you had better be ready." Computers are coming to the people.

This is perhaps clearest in the next section of his article, where with some trepidation, Weiser sketches a fictional scenario of what it would be like to live in a world of ubicomp. His protagonist here is Sal, a mother and Silicon Valley executive whose work and home lives are suffused with the sorts of technologies as well as interaction motifs that Weiser has been outlining. When introducing this segment, Weiser notes the difficulties of posing these sorts of fictional predictions. Like most futurists, too, he finds that he needs to present his image of an alternate form of life within a familiar frame, so as to highlight the specific transformations being posited. Our attention is thus inevitably drawn to the assumptions about the world in which the new technological arrangements will be situated. It is notable, for instance, that Sal works in a place quite like Xerox's own research facility—a place where she interacts informally with colleagues, manages her own professional obligations, works regularly from home, and spends her working hours engaged in a combination of design and writing. More broadly, Sal finds herself in the sort of workplace that, as in today's world, is already suffused with information technology—the kind of office environment into which the desktop personal computer was introduced and that it has now thoroughly colonized. Ubicomp does not therefore create new user constituencies, nor does it challenge the assumptions around which the workplace is organized; it instead augments these environments, replacing desktop computers with new devices (and creating a whole new demand for upgrading the technological environment). Sal, Weiser seems to say, is "us." Of course, the particularities of Sal's life providing such fertile ground for Weiser's imagined computational world are the same ones that locate ubicomp in a U.S. middle-class frame.

Nonetheless, Weiser's article struck a chord. It presented a new model for human-computer interaction—one that offered new challenges and motivated both design and engineering activities. For people working in hardware design, it opened up new opportunities by showing how small, specialized devices could play a role in larger systems. For researchers working in distributed systems, it created new challenges of scale as well as turning the spotlight on the interactional consequences of design decisions. Ubicomp, then, became an animating vision for a wide range of computer science research areas; rather than a new topic in itself, it supplied a new approach to a wide range of research topics, some old and some new.

While the pursuit of personal computing had been a unifying force for the laboratory in the 1970s, the 1980s had been a decade of consolidation that had also been marked by the fragmentation of collective attention into the traditional subdisciplines of computer science—mathematical theory, networks, distributed systems, programming languages, hardware design, graphics and imaging, and so forth. In reinvigorating CSL's research agenda, Weiser deliberately sought an approach in which each of these areas would have important contributions to make and that might in turn become a labwide program. Consequently, when the ubicomp research agenda spread beyond the walls of CSL and PARC, it did so in a way that created a new nexus for interdisciplinary engagement. Rooted in traditional areas of computer science research, especially the design of digital networks, mobile and embedded hardware design, distributed systems (research into software systems whose operation requires the coordination of several different network-linked components), and software architecture (the study of approaches to the decomposition and structuring of large-scale software systems), ubicomp emerged as a research area that drew on but extended each of these existing domains. Further, as ubicomp research moved beyond CSL, it came into more sustained connection with other ongoing areas of research, including HCI and computer-supported cooperative work (CSCW).

Weiser's articulation of a novel research program around ubicomp was in these respects remarkably successful. In other ways, though, it was less so. As a research domain, ubicomp has remained largely rooted in computer science, where it cuts across traditional affiliations and focus areas. Yet such technological developments clearly have had massive ramifications not simply in their economic import and associated transformations of the workplace but culturally too, in the ways in which the ideas of information, flows, and networks have become animating narratives for contemporary accounts of life and society (Woolgar 2002). So to the extent that ubicomp provides both a platform for encounters between people and technology, on the one hand, and an animating vision for technologically mediated interaction, on the other, it places itself (not always consciously) also into a broader disciplinary conversation with science and technology studies, sociocultural anthropology, and media and cultural studies. Weiser himself understood this. A slide from his keynote talk at the Association for Computing Machinery (ACM) Symposium on User Interface, Systems, and Technologies in 1994 is especially telling. Titled "Building Invisible Interfaces" it reads, "Start from arts and humanities: philosophy, phenomenology, anthropology, psychology, postmodernism, sociology of science, feminist criticism, your own experience." Under this, written in boldface type, is the following: "This is the most important part of the talk. You may not get it on first hearing. Patience" (Weiser 1994, slide 10).

Ubicomp after Weiser

Weiser died unexpectedly in 1999 after a brief battle with cancer. He was just forty-six years old and still a highly productive researcher and research manager at the time. In the years between the publication of the *Scientific American* article and his death, ubicomp continued to gain traction at PARC and found willing participants elsewhere. In Weiser's lab, ubicomp deployments still build on the work that he articulated in 1991 (Want et al. 1995). Elsewhere, context-aware computing research at EuroPARC and Georgia Tech involved both small-scale experiments (e.g., Lamming and Flynn 1994; Long et al. 1996) and medium-scale deployments (e.g., Want et al. 1992). There was also emerging research at IBM's Tokyo lab around cell phone applications and mobile banking (Scheter 2000). For the most part, ubicomp, as it was becoming known as, was centered on working prototypes, test beds, and experimentation.

By the time of Weiser's death, however, competing narratives were taking shape at other technology companies: ambient intelligence at Philips (Aarts and Marzano 2002; Aarts, Harwig, and Schuurmans 2001; Zelkha and Epstein 1998) and later adopted by the European Commission's Information Society and Technology Advisory Group (IST Advisory Group 2001; Riva et al. 2005), pervasive computing at IBM (Ark and Selker 1999), and proactive computing at Intel (Tennenhouse 2000). All these technology-future stories shared an orientation to the rapid growth in technology deployments, the growing importance of the Internet, and the challenges that consumers, government, and industry faced in negotiating a world rich in digital devices. They differed in their research agendas, however. For instance, pervasive computing at IBM had an explicit focus on mobile devices and phones, in addition to cars and homes, while proactive computing at Intel articulated an interest in machine learning, data processing, and algorithms as well as personal experiences with digital technologies.

During this same period of the late 1990s and early 2000s, at various U.S. and British universities, research that centered on ubicomp agendas was also commencing: the Aware Home Research Initiative at Georgia Tech (Abowd et al. 2000), Project Oxygen (Rudolph 2001) and later the Internet of Things (Gershenfeld, Krikorian, and Cohen 2004) at MIT, and Project Aura at Carnegie Mellon (Garlan et al. 2002) all bore a strong connection to Weiser's earlier articulations of ubicomp. They were centered for the most part in computer science departments. In the United Kingdom, by contrast, Equator, a multisite project across eight British universities, was formulated around the integration of physical and digital interaction and had a strong interdisciplinary component drawing on sociologists, ethnomethodologists, and social psychologists as well as computer scientists.

This latter project is a significant one because, perhaps more than many others, it starts to explicitly marry technological experimentation with