ARTICLE

The Work and Vision of Ubiquitous Computing at Xerox PARC

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EDITOR'S NOTE

Note abbreviation of **MWP**: Mark D. Weiser Papers. M1069, Dept. of Special Collections, Stanford University Libraries. Stanford, Calif.

This article explores the early development of ubiquitous computing, a research vision of computation embedded into everyday life which accompanied a concrete agenda of technological development. Attributed to Xerox PARC computer scientist Mark Weiser, this article traces the practical work of Ubiquitous Computing as deployed by Weiser in the late 1980s and early 1990s. Examining the concepts of Ubiquitous Computing alongside its prototypes, technologies, personnel, and financing reveals the often conflicting practical requirements Weiser, as manager of PARC's Computer Science Lab, used the vision to fulfill, and contextualizes the vision's intellectual organization within its pragmatic operation.

The most profound technologies are those that disappear," Mark Weiser began his 1991 article for *Scientific American*'s September special issue on "Computers, Communications, and Networks" [35]. Manager of the Computer Science Laboratory (CSL) of Xerox's Palo Alto Research Center (PARC), Weiser outlined a vision of computing which was fully integrated into the everyday lives of its users—a "constant background presence" which "does not require active attention" [35].

To achieve this vision, Weiser argued that computation must diffuse physically and perceptually into the everyday world—simply more powerful personal computers, he claimed, were insufficient: "By analogy with writing, carrying a superlaptop is like owning just one very important book. Customizing this book, even writing millions of other books, does not begin to capture the real power of literacy" [35]. With this argument, Weiser intended to eclipse a growing trend of desktop workstations,[1] started in no small part at PARC two decades prior [17]. He exemplified this alternative way of bringing computation into the world with three PARC prototypes of "Ubiquitous Computing" (Ubicomp, as PARC researchers quickly abbreviated[2]): tabs, "inch-scale machines that approximate active Post-it notes" [35], pads, "foot-scale [interfaces] that behave something like a sheet of paper," and boards, "yard-scale displays that are the equivalent of a blackboard or bulletin board." Connected together, Weiser proposed, these devices would collectively enable interactions with computer systems wherever it was most useful—allowing a user to focus on a conversation or task at hand while supported by a computer which would be perceptually "invisible."

Often carrying the title of "visionary" [6], [19], Weiser and his ideas continue to be frequently discussed within what is now a field of Ubiquitous Computing [8] alongside many neighboring research areas [16].

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[1]Nooney, among others, identifies the beginnings of personal computing to the mid 1970s: see [23].
[2]Mark Weiser. *Interns Talk (UbiComp)*. Box 61, Folder 13, MWP. 1988.

While an important intellectual voice, however, Weiser was also a manager of an influential corporate research lab. In that capacity, he engaged Ubiquitous Computing not just as an intellectual or inspirational exercise, but also *put it to work:* arguing for funding, changing perceptions among the public and within PARC, and motivating technologies and prototypes.

Centered on the collected papers of Mark Weiser [25], housed at Stanford University, this article brings together business documents, technical documentation, presentations, publications, and personal notes to examine the practical unfolding of Ubiquitous Computing technologies, prototypes, meetings, financing, and rhetoric.

This article argues that Weiser used Ubiquitous Computing concepts to give expression and direction to an existing CSL research program, to conceptually unify the CSL's broad range of research activities, and to mediate and make legible the work of the CSL to Xerox executives alongside broader academic, industrial, and public audiences. Analyzing the practical role of Ubiquitous Computing ideas at PARC also highlights how Weiser used new philosophical language and intellectual development to flexibly accomplish these ends within his practical constraints as a manager. In this light, Weiser's work of forming and sustaining the vision of Ubiquitous Computing was a continual negotiation of intellectual, social, and technological practice.

Previous discussions of Weiser's work focused on the intellectual community of Ubiquitous Computing and its self-conception [14], [15], which now encompasses many conferences, journals, and research areas [8]. These authors offer thoughtful engagement with the published record of Weiser's writings and the research legacy they have created. Kerasidou [14] engaged Weiser's published work to deconstruct Ubiquitous Computing as a social concept. They investigate how Weiser is rhetorically situated within a community, which sees itself as inheriting his research agenda [14]. Kinsley [15] similarly engages the "discursive and performative practices" of UbiComp practitioners, using UbiComp as a case study to understand modern technology corporations' rhetorical use of the near-future. While valuable social-scientific engagements of UbiComp concepts and its broader research community over decades of evolution, these discussions offer limited insight into the institutional unfolding of Ubiquitous Computing as it occurred at PARC. This article specifically presents a historical account of Ubiquitous Computing development from within PARC and the CSL (and Weiser's management of it) right at its inception, from 1988 to 1992.

Within historical literature, Tinnell presents an intellectual biography of Weiser [31]. Accordingly, Tinnell's account of Ubiquitous Computing uses Weiser as the central locus, narrating the development of Ubiquitous Computing through Weiser's philosophical inspirations, personal history, and intellectual perspective. While this article also takes Weiser as an important figure and relies on the same archive, it examines how these archival materials also present a picture of Ubiquitous Computing within the environment of PARC and the CSL, contextualizing Weiser and his deployment of Ubicomp within his practical role as manager.

Where Tinnell presents Weiser as "compel[ling]" a resistant CSL toward the radically new ideas of Ubiquitous Computing [31, pp. 101–102], this article traces the engineering, writing, and correspondence of the CSL to find a continuity of CSL research, reinterpreted and newly inspired by Weiser's intellectual leadership as a manager.

The focus of this article on the practical work of a technological "vision" echoes McCray's discussion of "visioneering" in space exploration and nanotechnology in the late 20th century United States [20]. McCray discusses how influential engineers-turned-visionaries garnered national attention, public and private funding, and the energy and excitement of many researchers toward their visions of a technological future. While Weiser's story has much in common with McCray's visioneers, Weiser's role as manager of CSL differentiated his work of building and maintaining a vision from McCray's subjects. While Weiser's vision was ambitious, it relied significantly less on major leaps in scientific knowledge [20, p. 17], as evidenced by how quickly working prototypes were produced. Furthermore, Ubiquitous Computing as a research program was advanced primarily through these prototypes rather than detailed design and extrapolation. Nevertheless, this work shares in McCray's focus on understanding the socio-technical deployment of conceptions of the future, examining the early development of Ubiquitous Computing as a social, intellectual, and technical process.

Weiser had inherited a lab which, a decade before, had used the vision of personal computing to build, among others, the *Alto* and *Dorado* systems [17]. After the departure of CSL director Bob Taylor and many CSL researchers in the mid 1980s [21, p. 49], CSL required a new vision toward which individual researchers could collectively contribute. This article examines the practical work of such a vision, and, for Weiser, the practical work of such a visionary.

FORMING UBICOMP

From the inception of Ubiquitous Computing, Weiser provided practical and conceptual

leadership—encouraging a series of visioning meetings and providing theoretical framings which gave the ideations of others a collective legibility. On the other hand, many researchers in the CSL helped elaborate and expand a vision of "integration" which Weiser eventually developed into Ubiquitous Computing.

"Many of us believe it is time to redefine, or at least restate, CSL's vision," read an email from Mark Weiser and John White, which initiated a series of "vision meetings" among researchers at the CSL in the spring of 1988.[3] As CSL research scientists, Weiser and White argued for the value of a "vision": a "directional...holistic, future-oriented...idealistic" agenda for the lab which provided a "unifying focus" even among the diversity of the lab's research.[4] Weiser and White (with other colleagues) presented an initial "seed" of a vision, centered around the "integration of people and the sea of bits."[5]

This vision suggested integration of computer systems on three levels: integrating computer interfaces with the physical environment ("the 'interface' must instead be a world in which people and computers jointly dwell"[6]), integrating software tools with each other, and, finally, long-term-interoperable computer systems.[7] While the details remained unclear, this initial formulation remained a core part of what later became Ubiquitous Computing.

These initial presentations spurred many small groups of CSL researchers to develop vision proposals of their own over the coming months,[8] culminating in a CSL visioning retreat on 17–19 November 1988[9] These vision proposals, ranging across hardware, software, interfaces, networking, and computer science theory, shared a similar theme of integrating people and machines; they included "persistent (ubiquitous, continuous)" information access across devices[10]; embedded, distributed computation[11]; electronics enriched documents[12]; and rich document/multimedia search, storage, and organization.[13] Shared among these proposals included a focus on interoperability between programs and operating systems; higher-level "meta-languages"[14]; portable, distributed, networked computing; and pervasive user interfaces which present information in flexible formats and form-factors. Each of these concepts became an important part of both the ubiquitous computing vision and the specific technologies CSL built in the following years.

At the same time, Weiser brought these individual perspectives together to propose a unifying lens. In his summary letter prefacing the retreat, Weiser collected and evolved these diverse calls for integration, proposing an overarching interest in "Integrated Plenary Heterogeneous Systems (IPHS)," or "research into the seams of our human and computer systems."[15] Seams, Weiser proposed, are "a joining, a useful tying together across a broad interface that makes something greater than the components."[16] By the date of the retreat itself, Weiser had already begun using the language of "seams" in his presentations, envisioning interconnected systems which understood the "relationships" between computing and the world—computing as a "ubiquitous integrated presence in everyday objects, like books, bookshelves, doors, telephones, wall[s], desks."[17] While Weiser's conception of IPHS incorporated many sentiments expressed by fellow CSL researchers, Weiser was also forming an independent vision of computing which was more broad and more fundamental than the individual scenarios, technologies, or interfaces proposed by others.

In a similar way, the notion of "integration" also seemed to incorporate much of the technical research program underway at CSL at the time. Projects in development by 1988 included systems research into portable software environments (PCR)[18] and scalable databases (Yggdrasil) [12]; Information organization projects into representation-independent document storage

[3]John White. *Abstract for Mini Dealer*. Box 31, Folder 7, MWP. dated Jun. 7, 1988 for a talk entitled "Building a CSL Vision". Jun. 7, 1988.
[4]Mark Weiser. *Building a CSL Vision*. Box 31, Folder 7, MWP. 1988.
[5]Mark Weiser. *Towards a Long-Range Vision for CSL*. Box 31, Folder 7, MWP. Jun. 6, 1988.
[6]Mark Weiser. *Towards a Long-Range Vision for CSL*. Box 31, Folder 7, MWP. Jun. 6, 1988.
[7]Mark Weiser. *Towards a Long-Range Vision for CSL*. Box 31, Folder 7, MWP. Jun. 6, 1988.
[8]Mark Weiser. *What I've Learned from Visioning So Far*. Box 31, Folder 7, MWP. Sep. 11, 1988.
[9]MarkWeiser et al. *Reading for Off-Site*. Box 31, Folder 12, MWP. Nov. 16, 1988.
[10]Jim Gasbarro et al. *Visioning Contributions of the BDV's*. Box 31, Folder 12, MWP. Jun. 16, 1988.
[11]"we expect there will be lots of computers, large and small, around, and there'll be a lot of communication between them" Hauser et al. *Our Report*. Box 31, Folder 7, MWP. Sep. 23, 1988.
[12]Frank Crow et al. *Raw Bits or Barely Baked Visions*. Box 31, Folder 7, MWP. Aug. 15, 1988.
[13]Jean Gastinel et al. *On Line Information, or the CopierLess Office*. Box 31, Folder 8, MWP. Nov. 16, 1988.
[14]Jean Gastinel et al. *On Line Information, or the CopierLess Office*. Box 31, Folder 8, MWP. Nov. 16, 1988.
[15]Mark Weiser. *What I've Learned from Visioning So Far*. Box 31, Folder 7, MWP. September 1988.
[16]Mark Weiser. *A View of CSL Visions*. Box 31, Folder 8, MWP. Oct. 13, 1988.
[17]Mark Weiser. *The Future of Computing*. Box 31, Folder 8, MWP. Nov. 8, 1988.
[18]Mark Weiser. *Spencer - Integration Overview*. Box 61, Folder 1, MWP. Jun. 8, 1988.

and retrieval (System 33),[19] and collaborative information feed organization (Tapestry) [30]. These systems were each referenced throughout the visioning process[20] and remained active research projects through the early development of Ubiquitous Computing.[21]

This CSL visioning process was also situated within the broader context of existing work at PARC. Outside of CSL, other laboratories (which were highly collaborative but generally self-directing) had other ongoing projects, which also influenced the ideas proposed at the retreat. A recurring touchstone for many proposals was room-scale display interfaces like "Liveboard," the large-screen touch interface developed by researchers in the Electronics and Imaging Laboratory (EIL), led by Richard Bruce and Scott Elrod [10]. The Liveboard was used by the Intelligent Systems Laboratory (ISL) to build the "Co-lab" (Collaboration Laboratory), led by Mark Stefik. Experiments within the Co-lab environment were first published in 1986 [28] and explored shared-information, realtime interfaces for office collaboration [11]. The interactions explored by the Liveboard and Co-lab environments clearly excited CSL researchers: As an example of how IPHS might affect CSL decision making, Weiser wrote that "...yet another CRT window system is less interesting than liveboards or portable information tablets."[22] "Liveboard/Liveroom" was voted the highest 5 year priority at the retreat.[23] In a June 16th presentation the week following Weiser and White's initial presentation, "Dynaroom" had also been proposed as a potential vision, referring to the same concept of a room-sized system of connected interfaces[24,25], with clear reference to the concept "Dynabook" computer envisioned by Alan Kay [13]. In this way, both the developing technologies and previous ideas at PARC beyond the CSL became a foundation for Ubiquitous Computing.

Many researchers in this visioning process, including Weiser, were also clearly interested in tablet interfaces as part of Ubiquitous Computing. Beyond the "portable information tablets" mentioned above, an article published that year on a concept personal computer, the "TABLET" [22], was included in the retreat materials. Alongside "seamfullness," Weiser also proposed the "PSlate," a stylus-based tablet computer, just a week before the vision retreat.[26] Also proposed was building a room-sized connected interface system "like co-lab did," but with smaller, connected devices.[27] Many vision proposals also included handheld, touch interface concepts like interactive documents ("magic paper"[28]), real time and collaborative portable interfaces,[29] and wireless, portable data retrieval[30]—all of which evoke aspects of what the ParcPad was later designed to achieve.[31]

The records from this visioning process show that while Weiser was certainly a conceptual leader, many researchers in the CSL helped elaborate and expand a vision of "integration." While the language Weiser and others used to describe this vision evolved throughout 1988 significantly, each iteration retained a focus on interoperability, contextual interactions and interfaces, and real-time communication and data-sharing, all of which had active associated research projects at CSL prior to Weiser's and White's call for a new vision. The Liveboard and Co-lab environment, already active projects in other labs at PARC, were common points of reference and ideation during the CSL visioning process. Tablet computing was also an interest among some CSL researchers at this time, with the visions discussed at the retreat capturing much of the ParcPad's ethos as an integrated tablet computer. Beyond the technical aspects, a conceptual focus around better "situating"[32] devices within the everyday lives of users remained a consistent part of the proposed vision. By the following year in 1989, Weiser settled on describing this ethos as "Ubiquitous Computing."[33]

BUILDING UBICOMP

Alongside the visioning process, the CSL continued to be an active research lab. As Weiser became manager, the language of Ubiquitous Computing began

[19]Mark Weiser. *A Slow File System*. Box 61, Folder 4, MWP. Mar. 3, 1988.
[20]Mark Weiser et al. *Current Activities*. Box 31, Folder 11, MWP. Nov. 1988.
[21]Mark Weiser and John White. "Ubiquitous Computing Program". In: *Semiannual Report, January Through June*. Box 43, Folder 9, MWP. Xerox Palo Alto Research Center, 1991
[22]Mark Weiser. *What I've Learned from Visioning So Far*. Box 31, Folder 7, MWP. Sep. 11, 1988.
[23]Mark Weiser et al. *5 Years Out: Priorities*. Box 31, Folder 11, MWP. Nov. 1988.
[24]Mark Weiser. 20 Year Visions. Box 31, Folder 7, MWP. Jun. 16, 1988.
[25]Jim Gasbarro et al. *Visioning Contributions of the BDV's*. Box 31, Folder 12, MWP. Jun. 16, 1988.
[26]Mark Weiser. *Forum Talk: Seams and Cloth: The Future of Computer Science Research*. Box 61, Folder 2, MWP. Nov. 8, 1988.
[27]Mark Weiser. *Towards a Long-Range Vision for CSL*. Box 31, Folder 7, MWP. Jun. 6, 1988.
[28]Mark Weiser. *20 Years Out Towards an Artifact Magic Paper*. Box 31, Folder 11, MWP. Nov. 1988.
[29]Hauser et al. *Our Report*. Box 31, Folder 7, MWP. Sep. 23, 1988.
[30]Jean Gastinel et al. *On Line Information, or the CopierLess Office*. Box 31, Folder 8, MWP. Nov. 16, 1988.
[31]Mark Weiser. *Beyond Workstations*. Box 61, Folder 9, MWP. Feb. 13, 1989.
[32]Mark Weiser. *Towards a Long-Range Vision for CSL*. Box 31, Folder 7, MWP. Jun. 6, 1988.
[33]Mark Weiser. *Interns Talk (UbiComp)*. Box 61, Folder 13, MWP. 1988

to frame some of these ongoing projects, presenting the research of the CSL as working toward a vision of Ubiquitous Computing even if the original inspiration of these projects preceded it. In addition, tracing the work of the CSL at this time reveals the slow and multifaceted technical development required for the tabs, pads, and boards to become a reality. These perspectives present Ubiquitous Computing as a negotiation between a guiding "vision" and the momentum of a research lab already in motion.

Near the time of the CSL vision retreat in November of 1988, Weiser transitioned to manager of the CSL.[34] From concepts of "integration" and IPHS which Weiser proposed during the visioning process, Weiser crystallized "three aspects of ubiquity," which guided his new research leadership: first, *pervasive*, that "every part of your life uses computation"; second, *interoperable*, that "everything, including pre-existing machines, computes together"; and *portable*, that "every place offers you your 'home' environment."[35] While the ParcPad featured among the research priorities for 1990, a majority of CSL projects from 1988 to 1990 had preceded Ubicomp, only now listed under a "Ubiquitous Computing Program" in PARC's corporate research report,[36] internal plans,[37] and press.[38]

Among these projects were three database-focused lines of research, which together reveal the informational infrastructure required beneath the physical tabs, pads, and boards of the Ubiquitous Computing vision.

Tapestry [30] was a filtering and priority system for email and news content. Funneling news articles into a relational database, Tapestry would run user-individualized filtering over the content (specified with user-defined rules), sending each user daily summaries with the goal of "enabl[ing] more effective communication between informal groups of people."[39] Based on similar rules, Tapestry also included *WallTapestry:* an email client to filter and prioritize email, for example, on the basis of specific senders or keywords. Tapestry was motivated as a Ubiquitous Computing project due to this *interoperability* between database filtering systems and email clients.

The Yggdrasil project explored how a database system could simultaneously present different data models [12], as either a *hypertext* database of objects and links, an *object-oriented* database of data and pointers, or a file server (NFS) of folders and files. From a Ubiquitous Computing perspective, this *interoperability* allowed a variety of applications to interface with a single database, shifting the "burden of interoperability" from the application to the database itself [30, p. 11].

System 33 took a database approach to document management and display, abstracting the contents of a document apart from a format or display method to allow queries and display specifications to render information "just-in-time" across a variety of file formats and data models.[40] This allowed users to access documents from databases in customized and consistent ways, fulfilling the UbiComp principle of *portability*.

Together, these three database projects reveal the *infrastructure* of the Ubiquitous Computing vision—underneath the hardware devices was a complementary line of research into the new generation of information storage systems required to support interconnected, ubiquitous devices.

Ubiquitous Computing also gave an explicit focus on interoperability and data portability to Liveboard development, with CSL researchers now experimenting with software interactions on the Liveboard.[41]

While it is unclear whether the vision of Ubiquitous Computing significantly changed the active development of these projects, Ubiquitous Computing nonetheless became a new language for motivating and discussing the work. Beyond databases, this was also true for the programming systems research at CSL. For instance, "Portable Common Runtime" (PCR) [1], [34] was a language-independent runtime layer to manage threads, memory (through universal garbage collection), I/O, and symbol binding which could be utilized from C, Cedar (a language developed by PARC researchers [29]), or CommonLisp, and could target a range of operating systems including Unix, SunOS, Mach, and bare-metal systems.[42] While the project was begun in early 1988 before the start of the visioning

[34]Mark Weiser. *CSL and Me*. Box 61, Folder 16, MWP. Jun. 1988.
[35]Mark Weiser. *PCR at SUN*. Box 61, Folder 13, MWP. May 23, 1989.
[36]Mark Weiser and John White. "Ubiquitous Computing Program". In: *Semiannual Report, January Through June*. Box 43, Folder 9, MWP. Xerox Palo Alto Research Center, 1991.
[37]Mark Weiser and John White. *Ubiquitous Computing Program: 1990 Plan*. Box 62, Folder 5, MWP. Nov. 3, 1989.
[38]Debra Feinstein. "Making Computers Invisible". In: *Benchmark IV.3* (1989). Ed. by Terry Dillman.
[39]Mark Weiser and John White. "Ubiquitous Computing Program". In: *Semiannual Report, January Through June*. Box 43, Folder 9, MWP. Xerox Palo Alto Research Center, 1991, p. 32.
[40]Mark Weiser. *A Slow File System*. Box 61, Folder 4, MWP. Mar. 3, 1988.
[41]Mark Weiser and John White. "Ubiquitous Computing Program". In: *Semiannual Report, January Through June*. Box 43, Folder 9, MWP. Xerox Palo Alto Research Center, 1991, pp. 38–42.
[42]Mark Weiser. *PCR at SUN*. Box 61, Folder 13, MWP. May 23, 1989.

process,[43] Weiser now emphasized the larger vision of ubiquitous computing in presentations and discussions of the project: that portable software across operating systems, languages, and hardware enables computer systems to work in concert to form an interconnected background—"interoperability without homogeneity."[44] The incorporation of existing research into a Ubiquitous Computing program highlights how Ubiquitous Computing not only inspired new research directions, but also gave new motivation and potential to existing research projects.

While "tabs" and "pads" were emblematic of the technologies and interactions inspired by Ubiquitous Computing, the iterative and involved development of working prototypes reveals the many perspectives, technologies, and research projects required to make Ubiquitous Computing more than a vision. Development on a tablet interface (called the PSlate initially as a concept tablet, later ParcPad as the overarching project) began in 1989. From the PSlate's inception, Weiser had conceptualized its design in concert with the Liveboard, as a similar architecture which could leverage common server resources, windows, and programs in real time.[45] In a 13 February 1989 presentation, Weiser speculatively proposed a possible "mini pslate,"[46] with a 2-inch by 2-inch display—a clear progenitor for the Tab. These proposed interfaces captured the other two themes of Ubicomp: pervasiveness, due to the diversity of interfaces, and portability, due to the intercommunication and common reliance on shared, networked backend storage and processing.

CSL researchers created two tablet interfaces between 1989 and 1991. The first, "Scratchpad" was a touchscreen interface which functioned as a separate display for a Sun Microsystems SparcStation.[47] As a separate display to a nearby machine, the scratchpad required a wired tether. CSL researchers additionally prototyped "Xpads," named because they functioned as an X terminal server,[48] and could be run over a wired or wireless network connection.[49] Developed to "simulate where general purpose foot-sized [ParcPad] Ubicomp devices might be in a few years,"[50] the Xpad enabled CSL researchers to experiment with networked tablet interfaces and resulting software interactions even if building a stand-alone tablet computer was technically infeasible. CSL also started active research in sufficiently high-bandwidth and low-power wireless local-area networks for these interfaces to function effectively.[51] Due to difficulties sourcing the screens for the Xpad, researchers later built smaller devices named "MPads" in 1990,[52] following similar architecture. A third concept, the "SPARCPad," was envisioned as a standalone workstation stylus tablet interface, but was not built.[53]

In the Winter of 1989, Weiser initiated the design of the ParcPad case (intended for both the scratchpad and Mpad[54]), and contracted the design firm Fitch Richardson Smith,[55] but due to budget and scheduling difficulties, Weiser transferred the project to David Kelley Design at the start of 1991.[56] During this design phase, Weiser used Ubicomp as a coherent doctrine rather than a loose set of aspirations, citing Ubicomp in the active voice in a design critique: "Ubicomp says computer use is informal."[57] Bill Buxton, then a professor of Computer Science at the University of Toronto and former EUROPARC Researcher, [4] consulted on the project,[58] due to previous experience with touch interfaces [3].

ParcTab development started slightly later at the beginning of 1991.[59] Roy Want, an engineer who helped develop the Active Badge system at Olivetti (the active badge [32], an Infra-Red-broadcasting name badge to register the real-time location of colleagues within the office, became part of the Ubiquitous Ecosystem within the year[60]) led the project as a new hire of Weiser's. By the

[43]Mark Weiser. *Spencer - Integration Overview*. Box 61, Folder 1, MWP. Jun. 8, 1988.
[44]Mark Weiser. *PCR at SUN*. Box 61, Folder 13, MWP. May 23, 1989, p. 28.
[45]Mark Weiser. *Beyond Workstations*. Box 61, Folder 9, MWP. Feb. 13, 1989.
[46]Mark Weiser. *Beyond Workstations*. Box 61, Folder 9, MWP. Feb. 13, 1989.
[47]Bob Krivacic et al. *Xpad Plan*. Box 97, Folder 7, MWP. Sep. 22, 1990.
[48]The X window system was developed by Project Athena at MIT. For more information, see [5].
[49]Bob Krivacic et al. *Xpad Plan*. Box 97, Folder 7, MWP. Sep. 22, 1990.
[50]Bob Krivacic et al. *Xpad Plan*. Box 97, Folder 7, MWP. Sep. 22, 1990.
[51]Mark Weiser et al. *CSL Operating Plan Presentation*. Box 62, Folder 12, MWP. 1989.
[52]Mark Weiser and John White. "Ubiquitous Computing Program". In: *Semiannual Report, January Through June*. Box 43, Folder 9, MWP. Xerox Palo Alto Research Center, 1991, p. 54.
[53]Mark Weiser. *Feedback on PARCPad Case Design*. Box 8, Folder 8, MWP. Sep. 10, 1990.
[54]Mark Weiser. *Feedback on PARCPad Case Design*. Box 8, Folder 8, MWP. Sep. 10, 1990.
[55]Mark Weiser. *Letter to John Rheinfrank*. Box 8, Folder 9, MWP. Jan. 29, 1991.
[56]David Kelley Design. *PARCPad Ubiquitous Computing System*. Box 8, Folder 9, MWP. Dec. 6, 1990.
[57]Mark Weiser. *Feedback on PARCPad Case Design*. Box 8, Folder 8, MWP. Sep. 10, 1990.
[58]Mark Weiser. *Comments on Buxton's Comments*. Box 8, Folder 8, MWP. Aug. 23, 1990.
[59]John Seely Brown. *Performance Appraisal*. Box 31, Folder 13, MWP. Review Year 1991. 1992.
[60]Mark Weiser and John White. "Ubiquitous Computing Program". In: *Semiannual Report, January Through June*. Box 43, Folder 9, MWP. Xerox Palo Alto Research Center, 1991, p. 41.

end of 1991, the team had finished a prototype of the tab, which had a stylus-interactive display and could communicate with a nearby computer via an infrared (IR) connection.[61] CSL budgeted 50 tabs for the following year.[62]

Although the ParcTab began development after the ParcPad and Liveboard, it quickly gained momentum: the "furthest along of the three" by May of 1992.[63] The Tab was not without its difficulties, however, and seemed to reach reliability by the following year. As Brian Bershad, Computer Science Professor at Carnegie Mellon University stated in a Ubicomp workshop at PARC, "The last time I saw the tab was about 6 months ago [Approximately November, 1992] and absolutely nothing was working. Completely not true today."[64] In that Spring of 1993, CSL researchers deployed the ParcTab within PARC, with IR transceivers installed and tabs distributed to about 25 PARC researchers [26]. By 1995, Want reported about 40 people at PARC who contributed to the ParcTab hardware and software development [33].

At the turn of the decade in Winter 1989, Weiser solidified Ubiquitous Computing as the conceptual ethos of the lab's direction: bringing computers into everyday life—to make "computing like breathing."[65] While the ParcPad featured among the CSL's research priorities, a majority of CSL research projects in the two years following Weiser's promotion had been ongoing, now motivated from a Ubicomp perspective. The ParcTab and ParcPad were both projects which took research teams multiple years to develop: under the surface of the ideas of ubiquity was a slow and comprehensive research program. Fundamental problems in building interfaces like these for the first time required new development environments and tools, new protocols and hardware for local area networking[66] and near-field radio [7], developing window and state management across devices, new database and information systems, and new software integrations and applications to explore how these devices might be used. All of these technological developments were required in order to make Ubicomp a research program in addition to a research vision. Through the lens of this technical development, Ubiquitous Computing might then appear as a collection of technologies already in progress which were given conceptual focus and expression, rather than a radical new insight of Weiser's.

THE RHETORICAL WORK OF UBICOMP

Using the language of Ubiquitous Computing, Weiser brought new energy and excitement to the CSL, inspired potential hiring candidates, rallied public new funding, and gave the CSL a newfound direction after the previous collective vision (personal computing and the Alto) had come to a close. To accomplish these goals, Weiser grounded Ubiquitous Computing in flexible, interpretive philosophical concepts to unify the lab's mission without forcing dramatic changes away from the independent, self-directed culture.

In bringing a research vision to the CSL, Weiser had to negotiate a complex tension between the internal culture of the lab and its external appearance. CSL was a group of about 50 research scientists,[67] each with their own interests and projects, and had a strong culture of self-directed work.[68] At the same time, Weiser was also interested in presenting a unified, collective image of the lab.[69] While Weiser presented CSL as "Our Primary Theme: We do Ubiquitous Computing,"[70] he stated that same year that "less than ten people [of fifty] in CSL are focused primarily on Ubicomp."[71] "Ubiquitous Computing" seemed, therefore, to shift between a broad, interpretive meaning, referring to, in Weiser's words, a "context that enriches, inspires, and challenges all of our work," and a narrow, concrete meaning, referring to research surrounding Tabs, Pads, and Boards.[72] In 1995 ethnographic study of the CSL, sociologist John Hughes underscores this shifting meaning: "...there is significant work going on in the lab which is not under the [Ubiquitous Computing] umbrella despite the fact that with a little interpretive license almost any aspect of computing can be made to fall under it."[73]

[61]Mark Weiser and John White. "Ubiquitous Computing Program". In: *Semiannual Report, January Through June*. Box 43, Folder 9, MWP. Xerox Palo Alto Research Center, 1991, p. 41.
[62]John White. *1992 CSL Operating Plan*. Box 31, Folder 13, MWP. Dec. 3, 1991.
[63]A.P. Brody. *Technology Licensing Opportunities*. Box 1, Folder 11, MWP. May 12, 1999.
[64]Brian Bershad. *Ubi Workshop Notes*. Box 52, Folder 17, MWP. Apr. 1993.
[65]Mark Weiser and John White. *Ubiquitous Computing Program*: 1990 Plan. Box 62, Folder 5, MWP. Nov. 3, 1989.
[66]This included the BADLAN project, an Asynchronous Transfer Mode (ATM) networking switch for local-area networks to support high-bandwidth networking across many co-located devices. See [18] for more information.
[67]Mark Weiser. *A Sense of CSL*. Box 31, Folder 5, MWP. Oct. 1991.
[68]Mark Weiser. *CSL and Friends*. Box 1, Folder 12, MWP. Jan. 27, 1992.
[69]Mark Weiser. *Visions*. Box 31, Folder 7, MWP. Jun. 8, 1988.
[70]Mark Weiser. *A Sense of CSL*. Box 31, Folder 5, MWP. Oct. 1991.
[71]John Seely Brown. *Performance Appraisal*. Box 31, Folder 13, MWP. Review Year 1991. 1992.
[72]Mark Weiser. *A Sense of CSL*. Box 31, Folder 5, MWP. Oct. 1991.
[73]John Hughes. *The Working Life of a Research Laboratory: Report for CSL, PARC*. Box 31, Folder 1, MWP. Sep. 8, 1995, p. 122.

As a manager, Weiser utilized Ubiquitous Computing as a concept to mediate between a lab of self-directed researchers and Xerox executives, making the broad work of the CSL legible and meaningful.[74] Hughes appears to have quoted Weiser on this legibility: "However, managing the lab does not seem to involve very much by way of formal direction, but is more a matter of "knowing sufficient[ly] about what's going on in order to tell a plausible story."[75] Weiser also seemed to be revitalizing the image of CSL and PARC for a broader community of academics and industry. John Seely Brown, then the head of PARC, wrote in Weiser's performance reviews that (in reference to his Ubiquitous Computing presentations) "you continue to play a pivotal role in convincing visitors that there's a renaissance at PARC"[76] and "You, single-handedly, are turning public opinion around and are well along the road toward making CSL the place to be again."[77] Weiser himself described CSL as "the lab that disappeared (externally)" in a retrospective presentation about his first three years as manager.[78]

At the same time, Weiser seemed to have genuinely inspired excitement in the CSL, using Ubiquitous Computing to offer a collective goal which CSL researchers could work toward. John Seely Brown commented that the vision "unleashed so much energy and received so much buy-in"[79] from the CSL. White later recounted that "Mark had significant vision and brought a new level of energy to running CSL" [24]. In Hughes' analysis, Ubiquitous Computing provided not just a way of making CSL research externally legible, but also internally coherent for CSL researchers themselves, providing "a vocabulary for talking about the work of the lab, a way of seeing its individual research activities as part of a coherent movement forward."[80]

CSL required this new energy and coherence: the departure of CSL manager Bob Taylor in 1983 and the close of research on the Alto, a desktop machine developed at PARC [17], had left the lab without a collective impetus. Hughes wrote that, reporting from many interviews with CSL researchers, "a sense [was missing] that the research might lead somewhere, might contribute to some larger goal"[81] following Taylor's departure. John Seely Brown highlighted this framing in a previously mentioned quote—that Weiser was "...making CSL the place to be *again*" (emphasis mine).[82] CSL researcher Scott Shenker wrote of the CSL visioning process: "Roughly twenty years ago [referring to the Alto], CSL started a revolution in the way people thought about computers. It is about time we started another one!"[83]

Weiser's ability to use Ubiquitous Computing to satisfy these many conflicting goals seems to partly stem from his use of philosophy to form a flexible but authoritative vision. From his coursework in philosophy as an undergraduate[84] and his philosophical engagements with computer science in graduate school,[85] Weiser was able to quickly rally thinkers like Heidegger, Gadamer, and Polanyi in the pages of Scientific American to substantiate his vision of invisible computers [35]. Weiser leveraged this philosophical background to assemble a broad range of intellectual allies for Ubiquitous Computing, pointing to "Philosophy, Phenomenology, Anthropology, Psychology, Post-modernism, Sociology of Science, Feminist Criticism..." as intellectual touchstones.[86] From this range of sources, Weiser made Ubiquitous Computing not just a vision of potential technologies, but a new way of seeing the world—a "context"[87] for thinking about computing research, that, in the words of John Seely Brown, "transcends both technological and intellectual concerns."[88] Weiser stated as much explicitly in a presentation: "the human/world distinction is a powerful and old artifact of Western intellectual tradition. To work on disappearing technology, we must adopt a different world view."[89] This use of philosophy and the humanities to propose a Ubiquitous Computing world-

[74] John Hughes. *The Working Life of a Research Laboratory: Report for CSL, PARC*. Box 31, Folder 1, MWP. Sep. 8, 1995, p. 93.
[75] John Hughes. *The Working Life of a Research Laboratory: Report for CSL*, PARC. Box 31, Folder 1, MWP. Sep. 8, 1995, p. 74.
[76] John Seely Brown. *Performance Appraisal*. Box 31, Folder 13, MWP. Review Year 1991. 1992.
[77] John Seely Brown. *Performance Appraisal*. Box 31, Folder 13, MWP. Review Year 1991. 1992.
[78] Mark Weiser. *Changing CSL, 1988-1991*. Box 31, Folder 13, MWP. 1991.
[79] John Seely Brown. *Performance Appraisal*. Box 31, Folder 13, MWP. Review Year 1989. 1990.
[80] John Hughes. *The Working Life of a Research Laboratory: Report for CSL, PARC*. Box 31, Folder 1, MWP. Sep. 8, 1995, p. 103.
[81] John Hughes. *The Working Life of a Research Laboratory: Report for CSL*, PARC. Box 31, Folder 1, MWP. Sep. 8, 1995, p. 103.
[82] John Seely Brown. *Performance Appraisal*. Box 31, Folder 13, MWP. Review Year 1989. 1990.
[83] Scott Shenker. *Hallucinations of a Heretic: A Computer Illiterate Looks Twenty Years Down the Road*. Box 31, Folder 10, MWP. 1988.
[84] Mark Weiser. *Language, Man, and Truth*. Box 143, Folder 9, MWP. 1971.
[85] Mark Weiser. *Can Intelligence Be Artificial? (Design for an Existential Computer)*. Box 145, Folder 2, MWP. Jan. 1976.
[86] Mark Weiser. *Building Invisible Technology*. Box 67, Folder 1, MWP. Nov. 1, 1994.
[87] Mark Weiser. *A Sense of CSL*. Box 31, Folder 5, MWP. Oct. 1991.
[88] John Seely Brown. *Performance Appraisal*. Box 31, Folder 13, MWP. Review Year 1989. 1990.
[89] Mark Weiser. *Interns Talk (Ubicomp)*. Box 61, Folder 13, MWP. Jun. 23, 1989.

view seems to have given Weiser license to make more substantial claims on the importance and authority of CSL research, having claimed in a presentation to the Defense Advanced Research Projects Agency (DARPA) that "Ubiquitous Computing is based on basic human and world properties—it is inevitable."[90]

While it is difficult to say what effect Weiser's philosophical grounding had on his ability to garner support for the lab, Weiser was certainly successful: he received a grant from DARPA in 1991 for $1.1 Million,[91] in Weiser's words, "CSL's first major government funding in a long time."[92] In a 1989 performance review, John Seely Brown praised Weiser's ability to excite potential hires with the Ubiquitous Computing vision.[93]

This broad and flexible view of Ubicomp, however, also seemed to lose specificity and coherence for some, as PARC researcher Eric Saund wrote after a Ubicomp workshop in 1993: "This nebulousness [of Ubiquitous Computing] was reflected in the frustrating utter lack of focus of my breakout group, an experience, I'm told, in other groups as well."[94] "This stands in troubling contrast," Saund continued, "to previous big visions such as Personal Workstations, Dynabook, Knowledge Navigator, or the Document Machine." Bob Krivacic, another PARC researcher, wrote for that same workshop that "There is such a wide range of definition, it is difficult to ascertain if a specific situation is ubiquitous computing or not. Mobility, sharing, communication, and agents all seem to have some connection to ubicomp, but how many of these concepts are necessary to ubiquitous computing?"[95] The failure of Ubicomp to fulfill both the role of a general context for interpreting research and concrete research program reveals the contradictory constraints the vision was asked to sustain.

Tracing Ubiquitous Computing rhetorically and socially reveals the conflicting requirements placed on the research vision: Ubicomp was used to flexibly describe a wide variety of computing research while giving a sense of coherent direction to researchers; it presented at some times a specific technical program of devices, interactions, and systems, while at others presented a technological worldview. Grounding the vision in philosophical concepts allowed Weiser greater interpretive flexibility and authority, but also seemed to jeopardize the sense of a coherent direction. Negotiating such a balance speaks to Weiser's competence as a researcher, intellectual, and manager, and seemed to have required that Ubiquitous Computing operate in all three domains simultaneously.

CONCLUSION

As Bell and Dourish write, Ubiquitous Computing might usefully be seen as "at once a technological and an imaginative effort" [9]. This article elucidates both of these dimensions and their relationship within the early years of Ubiquitous Computing at PARC. Ubicomp was a research vision deployed by Weiser to fulfill diverse and conflicting goals, emblematic of Weiser's own position as a researcher, intellectual, and manager. Within the corporate environment of Xerox, Weiser's public communication of UbiComp presented the image of a "renaissance at PARC,"[96] bolstering the public image of Xerox after its apparent stumble in capitalizing on the Alto [27]. While by the late 1990s, Xerox had increased pressure on PARC to develop more immediately profitable technologies [31, p. 286], the beginning of the decade saw Weiser successfully negotiate the interests and incentives of both those below and above him.

Although Ubiquitous Computing was first and foremost Weiser's vision, Weiser incorporated the perspectives, interests, and ongoing work of CSL researchers throughout visioning meetings. The vision of Ubiquitous Computing both inspired work on the ParcTab and ParcPad and brought new motivation and energy to existing work, including the Liveboard and PCR. The development and expression of these many research projects required the work of many researchers from across CSL and other labs in PARC, as Weiser used Ubiquitous Computing as a vision to make these diverse activities legible as a coherent collective project, to 'tell a plausible story"[97] to Xerox executives. Using the language of philosophy and the humanities, Weiser brought attention and funding to CSL, leveraging Ubiquitous Computing simultaneously as a vision of specific devices and also a context for interpreting a wide range of technologies and interactions.

Tracing the development of Ubiquitous Computing in the late 1980s and early 1990s reveals both a research program, a practical ordering and making-sense of the current work at hand, and a research vision, a

[90]Mark Weiser. *DARPA Talk*. Box 63, Folder 2, MWP. Nov. 25, 1991.
[91]Eric Steffensen et al. *Contract Pricing Proposal Cover Sheet*. Box 8, Folder 3, MWP. 1990.
[92]John Seely Brown. *Performance Appraisal*. Box 31, Folder 13, MWP. Review Year 1991. 1992.
[93]John Seely Brown. *Performance Appraisal*. Box 31, Folder 13, MWP. Review Year 1989. 1990.
[94]Eric Saund. *Ubiquitous Computing Workshop*. Box 52, Folder 17, MWP. 1993.
[95]Bob Krivacic. *Ubicomp Workshop Position Paper*. Box 52, Folder 18, MWP. 1993.
[96]John Seely Brown. *Performance Appraisal*. Box 31, Folder 13, MWP. Review Year 1991. 1992.
[97]John Hughes. *The Working Life of a Research Laboratory: Report for CSL, PARC*. Box 31, Folder 1, MWP. Sep. 8, 1995, p. 74.

justification of why a research program is worth pursuing. We might ask what relationship the program and vision of Ubiquitous Computing had: what the connection was between the working prototypes, technologies, and research papers, on one hand, and the philosophy, grand imaginings, and rhetoric on the other.

For Ubiquitous Computing, the program and the vision seems, to some extent, to have emerged together: with a vision emerging alongside or, arguably, even after the established program as Weiser reflectively took stock of the ongoing research at CSL and offered a vision which gave expression, direction, and inspiration to that program. His use of philosophy and the humanities in creating this vision was rarely of applying philosophical arguments or anthropological findings to the design of computer systems. Rather, theory and philosophy were also used here to give authority, legibility, and interpretive flexibility to a research program already underway. Reflecting on Kinsley's notion of "anticipation" as "making futures present" [15, p. 85], perhaps this account invites an interpretation of research visioning as both building imagined technologies, as "making futures present," while also bringing speculative meaning to existing research, as *making presents future*. Weiser's philosophical speculation also stands as an interesting counterpoint to McCray's analysis [20]—where "visioneers" extrapolated from physical laws and scientific advancement, Weiser used philosophy and humanistic arguments to extend the ideas of Ubicomp beyond their prototypes.

One way Weiser's conception of Ubiquitous Computing seems to accomplish his practical goals is through presenting a vision of how computing might *feel*, an *experience* of computing, rather than any specific technology or scientific finding. Ubiquitous computing *as a vision* was not about technologies, although it relied on them; it was not about interfaces, although it expressed its ideas through them; it was not about interactions, although it sought to enable them: rather, it was about a *feeling*—a felt quality greater than the sum of Ubicomp's parts. Arguably Weiser's greatest innovation was not on these previous three levels, but on a level of felt experience—Weiser brought together many existing threads of technological development to present a vision of Ubicomp, which was about the *feeling of being enabled by computers without thinking about them*.

This is perhaps well-suited for visions of human–computer interaction: if what is being built is ultimately an experience of computing, then a felt-perception vision of computing may be appropriate. On the other hand, this focus on a felt perception might allow Ubiquitous Computing as a conceptual framework to posit a vision that is resistant to critique because it has never quite yet come to pass. If Ubiquitous Computing, in Bell and Dourish's words, is perpetually "just around the corner" [2] because it relies on a felt experience of computation, it cannot be said to have failed or become obsolete like more concrete proposals of scientific discovery. Perhaps this specific case of Ubiquitous Computing suggests further study and critique on the *work* of such visions in human–computer interaction research: What currency they possess, what conceptual authority they rally, and what technological, societal, and experiential futures they promise.

Beyond questions of how Weiser accomplished Ubiquitous Computing, this article also raises questions about the purpose and origin of such a vision. It might be an unsatisfying question to ask how devices like tabs, pads, and boards *fit into* a Ubiquitous Computing vision, since the vision seems to have been constructed as an interpretive framework and worldview precisely so that "with a little interpretive license almost any aspect of computing can be made to fall under it."[98] Rather, considering the practical work of Ubiquitous Computing as a program *and* a vision might highlight the conceptual work involved in making a panoply of developing technologies be seen as collectively achieving a coherent, idealized future. The "visionary" work therefore, in this case, might be more about discovering and extending latent ideas in technological development, rather than imposing a vision of the future arrived at from without.

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