When Knowledge Transfer Goes Global: How People and Organizations Learned About Information Technology, 1945–1970

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This article argues that an information ecosystem emerged rapidly after World War II that made possible the movement of knowledge about computing and its uses around the world. Participants included engineers, scientists, government officials, business management, and users of the technology. Vendors, government agencies, the military, and professors participated regardless of such barriers as languages, cold war politics, or varying levels of national economic levels of prosperity.

In early 1953 a delegation from the Chinese Academy of Science (CAS) visited a number of computer facilities in the Soviet Union, and within a year the Academy had a team of engineers studying Soviet designs of computers then under construction. Subsequent delegations learned more, and in 1958, CAS built China's first computer, the *August 1*. All this happened just after a nearly half century of war and civil wars in China, events that were ruinous to the economy and educational development of the nation. Yet, here was China, early in the life of the computer, having built one. The initial "know-how" came directly from the Soviets, the same Soviet computer engineers who shared their knowledge with all of Eastern Europe, nations then in the Communist Bloc. The Soviets acquired a great deal of their understanding of computing from Western Europe and America.[1] In the same period of the late 1940s–1950s in the

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1. Zhang and Zhang, "Founding of the Chinese Academy of Computing Technology," 18–29.

West, Herman H. Goldstine, an early computer engineer working at the Institute for Advanced Studies in Princeton, New Jersey, hosted visitors from Western Europe and across the United States to learn about computers too, spreading state-of-the-art knowledge to at least a dozen countries.[2]

By the end of the 1950s a collective general body of knowledge existing about what constituted a computer and how to create one that was similar around the world was implemented by a relatively similar set of institutions in government, higher education, and in the West, in the private sector. Specifically, the know-how involved knowledge about how a computer worked, what components it required, how one built such a device (and its peripheral equipment, too), ran it, and, in time, grew it, as individuals and their institutions accumulated insights and practical knowledge about programming and software. Engineers also debated among themselves the advantages and disadvantages of implementing one design feature over another, much as people might debate features of a kitchen electric stove versus a natural gas one. Transfer of knowledge about computers involved each of these issues in the beginning, and then by the end of the period addressed here, it also included issues about best uses, their sale, and optimizing their costs. The early spread of such information proved crucial to the diffusion of computing from the 1950s until today. It occurred because of World War II, the Cold War, economic prosperity, communism, capitalism, shared languages (such as English, German, and Russian) despite differences in levels of technical and engineering capabilities, large-scale poverty, and regional wars. How did that happen?

Historians and economists are beginning to gain a global sense of the history of computing as it unfolded in some 100 countries, and the extent of its appropriation by organizations, industries, and societies. One discovery is that the deployment of this class of technology proved greater and occurred faster and earlier than once thought.[3] While the United States remained very much at the center of computers' global diffusion, strongly active in the various social and professional networks of experts, users, and supporters of the development and use of computers, a revised narrative needs to acknowledge the role of others in various countries working in governments, in business, and in research institutes and universities. Our understanding of what happened will need modifications, yet how extensive remains unclear. For example, we need to question

2. Goldstine, *The Computer from Pascal to von Neumann*, 349–62.

3. Cortada, *The Digital Flood*, and its extensive bibliographic discussion, 733–68.

the long-accepted argument that the world became users of computing largely because of the actions of IBM and big American corporations during its early decades. Other companies and agencies promoted use of computing too and, as this article will illustrate, often by appropriating IBM's technology without its permission (to the consternation of the firm), most dramatically in communist Eastern Europe. IBM remains important, but just not so significant as one might otherwise think.[4] A more nuanced story is emerging, more consistent with the diffusion of earlier technologies, such as telegraphy, telephony, precomputer data-processing equipment (e.g., calculators and punch-card tabulators) and "horseless carriages."[5] Many actors participated in spreading computers around the world, not just American institutions and companies; the stage is becoming more crowded with participants.

The story told here aligns in practice with the observations made by scholars from Nathan Rosenberg to Eric von Hippel that information about a technology emerges and spreads through the hands of many players, each acting in his or her own interests or as agents of institutions desiring to participate in the exchange. From notions of "black boxes" to "democratization of innovations," activities are global, surprisingly public, and crowded with various players.[6] While many of the protagonists introduced below were individuals, or groups of them, participants in this story were also employees of public and later, private institutions that funded their activities, often setting agendas for inquiring about computing and sharing information. Much of their work may seem informal, but this will clearly be familiar to readers who work in higher education, government research facilities, or in companies that are constantly keeping up with new technologies. While personal and professional networks were important for the diffusion of information about computing, these did not trump the role of organizations. Much was going on. For example, new professions were emerging, which in time structured the work of early computer builders, such as programmers, data-processing managers, and systems analysts. Moreover, dozens of professional associations formed, such as the IEEE Computer Society, and by the early 1970s several hundred colleges and universities established computer science departments and institutes in dozens of countries. In short, major institutions remained at the heart of information technology.

4. In the spirit of full exposure, I worked at IBM for over 38 years in various sales and management positions with clients all over the world and have an enormous respect for this firm's achievements.

5. Rogers, *Diffusion of Innovation*, particularly the fifth edition.

6. Rosenberg, *Perspectives on Technology* and *Inside the Black Box*; Von Hippel, *Democratizing Innovation*.

Thus both people and organizations are crucial to understanding the spread of computing.

Central to our emerging understanding of global diffusion of information technologies (IT) is shared knowledge. This article focuses on that phenomenon in computing's early decades, because without understanding of the technology adoption would have failed. That understanding had to occur at several levels to prove effective. First, computer engineering and mechanics had to be appreciated by potential builders, later manufacturers, of such engines and their assorted peripheral equipment (e.g., printers and tape drives). Second, there was the question of what one could use them for—applications being the term most widely used for the past half century—and why, or to what advantage. Third, operational insights were required, such as how to produce them in a factory, far away from making "one off" experimental devices in a laboratory, how to educate users, how much money was needed, and how should computers be maintained and eventually replaced? In the beginning these issues concerned only engineers and scientists, but very quickly military and civilian authorities, followed by private companies and, of course, potential vendors of actual technologies (components, computers, peripheral equipment, software) and services were also concerned.

Understanding how such information resulted in the construction and use of computing, while outside the scope of this article, cannot be completely ignored because they are serially connected, one activity following the other. Several early examples illustrate this. After World War II, participants in US wartime computing left the employment of the US military at the University of Pennsylvania, where they had worked on the Army's ENIAC device. They established a firm that eventually produced the UNIVAC, one of the most famous commercial computers of the 1950s.[7] Others working on military projects at the Massachusetts Institute of Technology (MIT), again for the military, relocated to dozens of companies and universities to continue working on IT.[8] Still others left active duty in the US Navy to form yet another commercial operation, ERA, in Minneapolis, Minnesota. Engineers from British projects migrated to postwar university settings, contributing to publicly available information about computers that translated into commercial diffusion. Electrical engineers who had worked with electronics during the war moved to private industry in the United States and in Western Europe; IBM hired such individuals for a new research function unit. In the 1950s and 1960s, a

7. Norberg, *Computers and Commerce*.

8. Unpublished survey results conducted of MIT engineers of the period in 1987, now housed at MIT Archive, provided by Deborah G. Douglas, curator of Science and Technology, MIT Museum, February 4, 2010.

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community of Soviet IT experts promoted computer use, led by Sergei Lebedev and his successors.[9] Similar links of people and information could be cited across Western and Eastern Europe to China and India, although in Asia they came largely from academia, not the military. The point is, links existed.

Diffusion of knowledge involved a combined near-simultaneous interaction of engineers, scientists, politicians, and business employees working in educational research centers, government agencies, user communities, publications and associations, and for vendors in scores of countries, sometimes independently, sometimes in collaboration. The term "user communities" needs explanation because it is important to our story. Frequently, groups of engineers interested in the technology built and operated these devices and so became experts focused on a computer system. For example, during World War II there were clusters of builders, then users, working for the American and British armies, and by the early 1950s, also for their navies and air forces. Scientists in the West and in the Soviet Union developing atomic bombs and ballistic missiles constitute other examples.

Often participants wore several hats, such as a company employee who might also be a scientist and a member of both an academic association and a fact-finding mission sponsored by a national government. While the notion of wearing "several hats" has not been the subject of considerable historical investigation, the role is understandable when someone has multiple loyalties affecting a decision. For example, an IBM salesman has to be loyal to the business interests of IBM, that is to say, sell its products, but also be her customer's advocate back to IBM, protecting the customer's interests by not promoting something that is not in that customer's best interests. Should an American scientist in the early 1950s have shared everything he knew about computers with Soviet fellow scientists, in the spirit of their profession's practice of sharing knowledge and being candid about technology? It is an issue worthy of further investigation; suffice it to say here that early computer developers often had conflicting motives, particularly when dealing with national defense or potential business competitors. The story of diffusion, and of its many hats, crosses professions, industries, roles, international politics, and wars.

The implications of so many participants actively spreading information about computing globally are not fully clear. However, one implication, the basis for this article, was that the diversity and number of participants made it possible for computers to be built and used across wide swaths of the world. It also appears that no one

9. Boris N. Malinovsky, *Pioneers of Soviet Computing*.

constituency could have done this by itself. The Soviets lacked commercial vendors promoting equipment, but in the West this proved a more effective channel of distribution than government agencies. Computer science professors could build "one-off" machines, but did not know how to manufacture machines by the thousands. However, office machine manufacturers and electrical equipment suppliers did, and they already had customers who might be receptive to this new class of "office appliances." Having political ties was important too, so communist Chinese government agencies could rely on Soviet government agencies for assistance, but could not reach out to the British or Americans with any confidence of aid. The complications are endless, but the point is clear: it was the combination of so many people and institutions that facilitated diffusion of knowledge and uses. This feature of the story distinguishes computing from earlier, less-complicated, or expensive technologies, but also evokes parallels with other modern technological diffusions, such as of aircraft and complex weapons systems.[10]

I would like to posit, but not explore here, the possibility that the network of the early experts, users, and their institutions was over time much larger than such communities for other technologies, such as aircraft, advanced weapons systems, and possibly modern ships. Indeed, those collecting and spreading information on computing became one of the world's largest communities of technological experts by the end of the 1980s, because so many individuals and their organizations had become reliant on this technology. The sheer scale of information diffusion after the period examined here suggests that perhaps the experience of the early computer experts was partially distinct from other cases and is particularly relevant to appreciate, since many of these individuals and their institutions played a continuing role in the diffusion of the technology into the twenty-first century.[11]

By the late 1940s groups of individuals around the world familiar with computers knew each other and met back and forth, trading information about this new technology, read each other's scientific and technical papers and books, and often worked for similar agencies, academic departments, and companies. Later they were joined by millions of clients and customers who bought, operated, and

10. For many examples and parallels, see Ruttan, *Technology, Growth, and Development.* I had in mind also military technologies given in works such as Mahnken, *Technology and the Americanization of War Since 1945*, Rattray, *Strategic Warfare in Cyberspace*, and Monmonier, *Spying with Maps*.

11. In addition to my experience of working in the IT industry, hundreds of obituaries of members of the computer information ecosystem document their work straddling the generations from roughly 1950 to 2000, routinely published in each issue of the *IEEE Annals of the History of Computing*, among others.

relied on computers. I refer to all these various individuals and their employers collectively as an information ecosystem.

From that globally emerging information ecosystem came knowledge about computing of sufficient value to warrant subsequent commitments by companies and governments to expensive investments that led to current worldwide annual spending of over $5 trillion on IT.[12] This experience calls into question the more traditional supply-side narrative: historical accounts featuring computer vendors as the primary protagonists, who proved effective in selling their products in highly developed economies. Increasingly, consumers also had an important role to play by using these technologies, often influencing their subsequent evolution, much as one sees today in the interactions of consumer-electronics manufacturers and their customers, as the former introduces new product models, such as mobile phones with new functions.[13]

Growing awareness of the information ecosystem's diversity also suggests that IT historians, in particular, could go beyond their normal practice of examining only national experiences with computing, embracing research agendas that are more global in scope in order to more fully appreciate the external forces impinging on what otherwise would be more narrowly based accounts. Knowledge about and influence of computers did not end at a country's border. The experience of early computer builders demonstrates that the work of governments, businesses, customers and users was highly integrated and interrelated, if not always formal and organized, and that professional practices and external forces and events (e.g., Cold War politics) proved highly influential, if not always obvious or public. Ultimately, I attempt here to explore some features of how societies embraced the many new technologies that flowed from both the Second Industrial Revolution and what some argue is a Postindustrial Revolution.[14] This essay ends with a few brief conclusions and suggestions for further research.

To accomplish that task, we look at the experiences of four communities over time. All operated simultaneously and were affected by each other, although they are described in sequence. First we visit the

12. The volume of expenditures is constantly changing and the subject of controversy. I discuss these and related issues more thoroughly in Cortada, *The Digital Flood*, 3–42.

13. I encountered numerous examples of the interactive relations between customers and vendors across 36 industries reported in the three volumes of Cortada, *The Digital Hand*.

14. Our discussion is influenced largely by the work of economists working with historical context, in particular Nelson, *The Sources of Economic Growth and his Technology Institutions* and *Economic Growth*, Baumol, *The Free Market Innovation Machine*, and Hall and Preston, *The Carrier Wave*.

engineers and scientists who originated the technology and actually built the first two generations of computers in the 1940s and 1950s. The second cluster is vendors and suppliers of such systems, largely American and European multinational firms and Soviet computer ministries that attempted to provide users with computing capacities. Customers constitute the third constituency—users—yet often also members of the first two groups who collaborated through user communities, conferences, publications, and visits to one other. The fourth community, only briefly discussed, since it has been the subject of much historical research already, involves large organizations, such as government agencies, military establishments, and universities. These four broad communities help us to identify at a general and global level patterns in the spread of information about computing. They contribute to understanding how this technology was adopted, and when appropriate, modified to meet local circumstances. Collectively, they offer a reference point for others who would want to study the activities of a specific organization or individual, hopefully offering relevant contexts in which to help situate the work of their subjects of investigation.

Several patterns of knowledge diffusion existed in the activities of these four, communities, reflecting similar behaviors in the appropriation of computing around the world. Before vendors sold computers and users of such systems came into being, knowledge about information technologies (IT) routinely flowed first into a country, industry, and organization, reaching small groups of engineers or scientists (both civilian and military). Initial awareness proved essential before the next step—early experimentation with computing—subsequently providing sufficient education to technical advocates, general and staff management, and potential users needed to create the necessary levels of demand, commitment, funding, and staff to install and operate the technology.[15]

The learning activities roughly paralleled the geography of adoption. Thus, knowledge-transferring activities occurred most often and earliest in the United Kingdom and the United States, where the bulk of early development took place (1930s–1940s), continuing to promote information diffusion during the rest of the century. Soon knowledge acquisition commenced in Western Europe (beginning late 1940s to early 1950s), and spread across Eastern Europe (early 1950s to mid-1960s), into Japan, India, and Australia (1950s–1960s). The pattern extended subsequently across other parts of Asia, such as South Korea, Singapore, Taiwan, Hong Kong (1970s), China (1980s), to currently emerging new adopters, such as Malaysia, Thailand, Philippines, and

15. For 16 country case studies, see Cortada, *The Digital Flood*.

Vietnam (2000s). In this process, local experiences and experiments added to the global supply of computing knowledge.[16] In Latin America the largest economies and industries were the first on board—Mexico, Brazil, and Argentina in the 1960s–1970s, followed by Paraguay, Chile, and Peru (1980s–1990s), and a new crop of societies, such as Costa Rica, Trinidad, and Cuba (2000s).[17] Africa as a whole is currently experiencing the appropriation of IT, mimicking some other countries, in particular experiences of the Asian Tigers and the industrial eastern provinces of China, although that history awaits scholarly attention.[18]

Once information began penetrating them, local communities interested in the technology sustained and added to their knowledge, reaching out to new entrants around the world familiar with the technology and its uses with the result that an information ecosystem emerged. Again, "information ecosystem" references a collection of knowledge, experts, and users much as academics think of a discipline (i.e., economics, history, or physics), but with the important difference that this body of knowledge and associated communities were far broader (larger too) than a scholarly discipline. The computing information ecosystem became denser and larger, generating ever more information, more current knowledge of the technology, a greater variety of participants, voluminous foreign and domestic published sources of information, expanding experience with international and local training, and integrating learning experiences across borders. This last is what occurred in IBM R&D labs that were populated with many nationals under one roof in a growing number of facilities around the world.[19] These patterns of knowledge diffusion, in place by the late 1960s, have remained remarkably stable to the present, which is why examining some of the specific activities prior to 1970 holds out the potential of useful insights into how businesses, industries, indeed whole national economies, came to embrace various technologies in the second half of the twentieth century.

Role of Engineers and Scientists

Quite early, engineers and scientists developed the initial information ecosystem for computing, beginning largely during World War II,

16. Ibid.

17. Aguirre and Carnota, *Historia de la Informática en Latinoamérica y el Caribe*.

18. Oyelara-Oyeyinka and Rasiah, *Development: Innovation and Learning in Asia and Africa*; on Africa the best source are scores of economic reports by the World Bank, e.g., Ottevanger, Akker and Feiter, *Developing Science, Mathematics, and ICT Education in Sub-Saharan Africa.*

19. Case study, Norberg and Yost, *IBM Rochester*.

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exchanging information, experiences, and insights about devices that might help break coded military messages, for calculating artillery firing tables, and later, conducting the complex mathematics needed to develop atomic bombs. On the Allied side, British and American computer builders collaborated on war applications with the support of their military commanders and scientific advisers to leaders like American President Franklin D. Roosevelt and British Prime Minister Winston Churchill.[20] The builders were university and government employees; in the immediate postwar period some became entrepreneurs, or worked at IBM (United States) or Machines Bull (France), among hundreds of others, while yet others continued crafting new systems at universities in over a dozen countries. Regardless of where they worked, they evolved quickly into a community that created and shared information about computing with few barriers imposed by their employers. In the 1950s the exigencies of Cold War politics began to slow the flow of information, further constrained in the 1960s by corporate concerns to patent new findings and augment competitive capabilities. This virtual community continues to exist. As the de facto source of new ITs for three generations, its members need to be studied as an historical community whose members embedded themselves in businesses, universities, and government agencies.[21]

The largest groupings of such experts at the end of World War II clustered in the United States, mainly in Boston and Philadelphia, with pockets scattered elsewhere (in Minnesota and southern California). In Great Britain, most located initially at Bletchley Park (home of wartime code breaking) and increasingly at such universities as Manchester and Cambridge.[22] By 1950, the British had commercial participants in their information ecosystem, most successfully those at J. Lyons & Co. who built LEO I (Lyons Electronic Office I), one of the earliest computers, if not the first, put to work in a business environment.[23] Perhaps there were 1,000 computing "experts" in 1946–1948; we do not know for sure. Immediately after 1945, a series of computer seminars were held, largely in the Boston area, with attendees from the United States, Britain, and Western Europe, representing academia,

20. Rees, "The Mathematical Sciences and World War II," 607–621; Burke, *Information and Secrecy*; Hinsley and Stripp, *Codebreakers*.

21. We do not know how many individuals comprised this ad hoc community; my attempts over the past 30 years to count them are yet to yield good numbers, but I believe that in the period examined here, by 1960 that number had to be well over a half million, over 5 million by the end of the century.

22. Aspray and Campbell-Kelly, *Computer*; on Manchester system, see Simon Lavington, *A History of Manchester Computers* (2nd ed.).

23. The subject of a growing number of studies, P. J. Bird, *LEO;* D. T. Caminer, J. B. Aris, P. M. Hermon, F. F. Land, *LEO,* among others; but see also Frank Land, "A Historical Analysis of Implementing IS at J. Lyons"; Campbell-Kelly, *ICL*.

office-appliance manufacturers, governments, and telecommunications firms.[24] After patenting a transistor in 1947, AT&T began to share information about the technology with US firms and scientists. Then in April 1951 it held a seminar on how to make transistors for over 30 companies from the United States, Europe, and Japan. Attendees were licensed to manufacture transistors in exchange for a fee.[25]

Simultaneously, engineers visited American and British sites to learn about computing's rapidly diversifying technologies. Reports prepared by American embassy employees in the 1940s and 1950s document trips by Europeans to US computer sites, of which there were then about 20.[26] Scientists, mathematicians, and engineers from Great Britain, France, The Netherlands, Norway, Sweden, Denmark, Italy, Austria, and Switzerland represented government agencies, banks, insurance companies, and office-appliance firms.[27] Very quickly those interested established transatlantic connections. Most spoke English, and all read the key journals in the emerging field, published by the Association for Computing Machinery (ACM) and later the Computer Society. Historians are familiar with many of their early projects, because so many computer pioneers wrote memoirs or published descriptions of their machines and software.[28] The US embassy reports were circulated based on mailing lists that included up to 100 officials in US government agencies, leading engineering schools, and engineering and science divisions of high-tech firms like IBM, NCR, General Electric, and RCA. These individuals briefed foreign delegations throughout the 1950s, as Herman H. Goldstine did at Princeton's Institute for Advanced Study. Goldstine hosted British visitors in 1946–1947, Swedish engineers in 1947–1948, Norwegians the following year and again in 1952–1953, plus others from Switzerland.[29] All through the 1940s–1960s academics reported their findings in numerous academic publications as well.[30]

There was little evidence that information gathering and sharing was a benign activity. Government employees were motivated by wartime

24. Cortada, *The Digital Flood*, 45–50.

25. A. Tradup, T.N. Pope, and H.A. Affel, "Memorandum: Transistor Symposium," April 27, 1951, File 11-04-02-02, AT&T Archives.

26. These were prepared by American intelligence agents, commercial attaches, and academic experts invited to visit and report on local conditions. In addition to such reports located in embassy country files (US Department of State records, US National Archives), there are two collections of such reports conveniently available: Blackman Papers, National American History Museum, Smithsonian Institution, and the Goodman Papers at the Charles Babbage Institute, University of Minnesota.

27. Various country reports in Blackman Papers, Boxes 216 and 217, National American History Museum, Mathematics Branch, Smithsonian Institution.

28. For extensive discussion of this literature, see Cortada, *Digital Flood*, 733–68.

29. Goldstine, *The Computer from Pascal to von Neumann*, 349–62.

30. Used extensively in Cortada, *The Digital Flood*.

needs and later Cold War security considerations to apply technology to weapons systems. Government agencies often funded academics and engineers around the world to develop systems designed for economic, scientific, and military purposes. In free-market economies, commercial computing was the key driver. Initially, all focused on scientific computing, because the technology proved better at calculating solutions to mathematical problems than in storing information. Later, as memory systems improved, nonscientific computing became possible and, therefore, of great interest too, as the development of the LEO I, and later computers from American suppliers suggested.[31]

Most visitors worked at newly established institutes of mathematics, engineering, or technology. By the late 1960s almost every country in Europe had such organizations, few of which have been studied by historians in any thorough manner, let alone their interactions with electronics firms and universities. Yet, these not-for-profit organizations were often the first computer developers around the world, rather than the more familiar IBM, Burroughs, CDC, ERA, ICL, or Machines Bull.[32] Memoirs make it clear that delegates and hosts shared information in a relatively candid manner: what they were doing, how it was going, and challenges of both technical and budgetary nature. They debated the technical options regarding components, computer architectures, and the pros and cons of design and practices. Employees at these nonprofits often worked for early commercial computer producers and moved back and forth between public- and private-sector jobs on both sides of the Atlantic.[33] Scientists and engineers were open about their shared intellectual interests with fellow scientists and engineers regardless of nationality, while business hosts were also motivated to promote the technology's benefits, leading to possible sales. The scarcity of information about military applications suggests that only in that sphere was there less openness. Military computing remains a key area in computing's history still in need of investigation.[34]

The small open community expanded into thousands during the 1950s and 1960s. The members of this community left a paper trail

31. On business motives, e.g., see John Aris, "Inventing Systems Engineering."

32. An excellent example of historical research on these kinds of initiatives involves French experience, Pierre E. Mounier-Kuhn, *L'informatique de la seconde guerre mondiale au Plan Calcul en France.*

33. Memoirs of such individuals have been published on a regular basis for some 30 years by the *IEEE Annals of the History of Computing*, representing the largest source of such information. Recently an index of all issues of this publication was prepared and made available through various Internet sources, "Combined annual indexes of the *IEEE Annals of the History of Computing*," Charles Babbage Institute, University of Minnesota.

34. Notwithstanding the excellent book by Paul N. Edwards, *The Closed World*. Uniformed military officers who are historians have acknowledged to the author the existence of of records of early computing over the years, but that information remains classified and is not open to historians.

useful to historians. Most published either in English or German, but reports also appeared in every major European language. The most widely circulated articles could be found in US journals; European institutions subscribed to these on a regular basis by the early 1950s, insuring the wide availability of much current information, and Asian libraries subscribed to these by 1970.[35] One German bibliography documents that nearly 20,000 articles and other publications had appeared on computing and related topics between the end of World War II and the mid-1960s; historians have rarely studied these.[36] Readers should find this pattern of behavior similar to what occurred with other emerging bodies of technical knowledge of interest for military and commercial purposes, such as aerodynamics, biotechnologies, and most recently, military and civilian space travel. While the links among all these have yet to be explored, they existed, because of engineers' and academics' shared work habits and their shared sources of funding for research and travel (e.g., DARPA in the US Department of Defense).

Valuable insights may be gained from examining these materials. For example, the orthodox view of the birth and development of cybernetics holds that this was largely an American story, yet the publication record shows that, simultaneously in the 1950s, much was going on in over a dozen West and East European countries.[37] Indeed, there may have been more Europeans working on cybernetics than Americans. Cybernetics, like so many other subfields of computing, had become an international project by the mid-1950s, a decade earlier than when the computer hardware industry became international.[38] A sense of community emerged in the 1950s and 1960s, paralleling that of computer vendors. It was a visible community, because engineering travelers wrote about their visits and findings. For example, American computing and engineering publications all through the period discussed US delegations' encounters with Western and Eastern European computing communities, often as byproducts of trips commissioned by associations, such as the ACM and the Computer Society, funded by universities or governments.[39]

35. Aa, *International Computer Bibliography*; FUNDP NAMUR, *Belgium Computing Literature.*

36. Various titles as these were published in 73 reports, supported by Deutsche Forschungegemeinschaft—DFG (1954–1966). A complete set is available at the IBM Laboratory Library, Zurich, Switzerland.

37. Stachowiak, *Denken und Erkennen im kybernetischen Modell*, 245–61.

38. See, e.g., about Soviet activities, Gerovitch, *From Newspeak to Cyberspeak,* and in East Germany, Werner, *Kybernetik Statt Marx?*

39. Often reported on by industry watchers, such as AUERBACH, *European Information Technology*, and by academic and government experts, Goodman, "Computing and the Development of the Soviet Economy," and his "Soviet Computing and Technology Transfer," 539–70; also academics and engineers publishing trip reports, such as Car III et al. "A Visit to Computation Centers in the Soviet Union," 8–20.

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A second, smaller, but just as enthusiastic and well-informed information ecosystem of experts developed beyond the Iron Curtain, comprising similar cohorts working in Eastern Europe and the USSR. Communist states created engineering institutes, extensively in East Germany and in the Moscow metropolitan area, with Moscow serving the same focal role as the metropolitan areas of Boston or Washington, DC did for Western activities. A similar pattern of visiting delegations from Eastern Europe to Moscow operated, slowing only by the mid-1960s as the Soviets began to worry that technical information would seep into the West, particularly out of East Germany. Records of these visits demonstrate that Eastern Bloc conversations were also relatively open and candid, even involving Americans when they came to Moscow to meet with fellow engineers, mathematicians, and scientists and, conversely, involving East Europeans and Soviets in the United States, visiting laboratories, academics, and eventually, computer makers by the early 1960s. Cold War politics hardly affected some participants who, like their American–West European colleagues, disseminated information about computer developments, advised each other, and debated various technical approaches.[40]

Yes, espionage did occur on both sides of the Iron Curtain, particularly with respect to weapons systems, most notably nuclear warheads and missiles, but also in telecommunications and military computing. The reality is that no one community, profession, or type of institution or agency could secure a monopoly on information technologies; too many participants were involved. While tight controls were in place during World War II, the lid came off the secrecy surrounding computing by the end of 1945, especially in Britain and the United States, where experts went public by doing IT research at universities as others commercialized the technology.[41]

Construction of computers in the Soviet Union, beginning in the late 1940s, led Moscow's evolution as the dominant site for Eastern European computing, particularly at the Institute for Applied Mathematics of the Academy of Science, where the leading Soviet expert on computing in the 1950s and 1960s, Sergei A. Lebedev, built machines, advanced Soviet knowledge of computer science,

40. Gerovitch, *From Newspeak to Cyberspeak*, passim; on Russian information, Gros, *Russian Books on Automation and Computers*; Prokhorov, "Computers in Russia: Science, Education, and Industry," 4–15; on East Germany, Cortada, *The Digital Flood*, 277–93.

41. The notable known exception was also Great Britain, involving the Colossus, a World War II project that remained secret by scores of those involved with its construction and use until the 1970s when details began to seep out. For details about this computer, see Hinsley and Stripp, *Codebreakers*, which includes a bibliography of events from the 1970s.

and hosted numerous visits from interested parties from Eastern Europe.[42] From the late 1940s to the demise of the USSR, Soviet computing's form (technical architecture) relied overwhelmingly on Western technical developments, not the least of which were American minicomputers, IBM's computer architecture and operating systems (software) of the 1960s and 1970s, and wide use of the European programming language Algol.[43] Knowledge of these technologies was obtained in various ways: employees read the Western technical literature; Eastern European embassies bought and collected publications; agents filched technical manuals (such as those describing IBM computers and their operations) or acquired machines and reverse-engineered them (a strategy Soviets became quite adept at with other Western technologies, e.g., military aircraft), and visited users in the West.[44]

In addition to first hundreds, then thousands, of individuals interacting from Moscow to San Francisco, and across agencies, academia, institutes, vendors, and users, publications multiplied. Beginning in the late 1940s, journals and later books began appearing in the United States and across Europe, describing the new technology. Much of this literature originated in the United States, written by engineers and computer scientists, the United States remaining to this day the geographic source for the largest volume of computing materials. Associations and user groups were prolific, collecting and codifying knowledge about computing, while shaping the emerging computer science discipline and associated professions. Leading publishers included the ACM (founded 1947), Data Processing Management Association (DPMA) (1949), IEEE Computer Society (1951), Society for Computer Simulation (SCS) (1952), and SHARE (1955), a user's group that published annual conference proceedings. New organizations continued to appear into the twenty-first century, many offering more than one flagship publication. Indeed, the ACM and the Computer Society sponsored dozens of journals that rapidly became globally key sources of information.[45] Book publishers in the early 1950s—Prentice-Hall and John Wiley & Sons among others—joined

42. For biographical information, Glushkov et al., *Sergei Alekseevich Lebeder*.

43. Davis and Goodman, "The Soviet Bloc's Unified System of Computers," 93–122, see also, Judy, *The Riad Computers of the Soviet Union and Eastern Europe, 1970–1985.*

44. Subject of some scholarly investigation, Cave, *Computers and Economic Planning*; Parrott, *Politics and Technology in the Soviet Union*.

45. A near flood of publications was launched by these organizations, most of which are still being issued: *Mathematical Tables an Other Aids to Computation* (1943–1960), *Computers and Automation* (1951), *Association for Computing Machinery Journal* (1954), *Datamation* (1957), *IBM Journal of Research and Development* (1957), *Computer Journal* (1958), and *Computerworld* (1967).

the flow, generating thousands of books in English, plus translations, over the next several decades.[46]

In addition to addressing evolving technologies, these articles and books documented reciprocal trips by Americans, Western and Eastern European engineers all through the 1950s, 1960s, and 1970s, describing trends in computer developments in various countries, which paralleled reports written by US government personnel.[47] These reports are insightful. Taking one example among many, American engineers visiting Moscow in May 1959, found their Russian hosts remarkably familiar with American computer developments and current on Western debates. They soon learned about the All-Union Institute of Scientific Information (VINITI), which routinely translated into Russian, English-language articles on all manner of technologies—not just computing—extracted from approximately 2,000 publications.[48] The East Germans did some translating too, although more engineers there could read Western languages, including English. By 1970, a host of Soviet and other East European publications on computing had become available too, provided by government agencies, including translations of American, English, and West German books on computing.[49] By the late 1950s, but even more so thereafter, Chinese and Indian engineers and other computer builders used Soviet libraries and institutes as sources for the same information available in the West. Before 1960, dozens of countries read the same literature, their engineers visited one other, while governments continuously acquired publications, supported travel for fact-finding missions, and, of course, funded building computer systems.[50]

Role of Vendors and Nonprofit Suppliers

Historians understand better the roles played by computer vendors and national governments in computing's diffusion, so here we will outline how suppliers fit into the information ecosystem that

46. Cortada, *The Computer in the United States*, 102–12.

47. Hundreds of such publications appeared, e.g., Bruijn, "Recent Developments in the European Market," 25–6; Computer Consultants, Ltd., *European Computer Survey*; *Datamation*, "*Datamation*'s International Computer Census," 46–8; Walther, "German Computing," 27ff; Auerbach, "European Electronic Data Processing: A Report on the Industry and the State-of-the-Art," Morse, "Automation Outside of the United States," 117–26; Berenyi, "Computers in Eastern Europe," 102–6.

48. Ware, "Soviet Computer Technology—1959."

49. For a large sampling of this material, see "Russian Soviet and Eastern Bloc Computing Collection, 1956–1996." See also Charles Babbage Institute's finding aids for further collections, http://www.cbi.umn.edu/collections.

50. Wilczynski, *Technology in Comecon*.

quickly developed after the war. Commercial computing began in the 1950s, largely in North America and in Western Europe, rapidly spread to Latin America and Asia starting in the 1960s, creating a global market by the dawn of the 1970s.[51] To get started, electronics and office-appliance firms relied on prior technical knowledge, their pre-existing sales organizations, and earlier industry practices into which they slotted this new product class. After 1945, they hired and developed expertise in the advanced electronics created during the war and established centers for computer product development. European and American vendors also used these laboratories and manufacturing sites as education centers, bringing customers in to learn about the new technologies and to train their own personnel. The most influential vendors were multinational enterprises that achieved economies of scale and agility necessary for worldwide marketing. Those that focused largely on national markets, often the first to appear in the computer industry, did not achieve that level of economic influence. So, the role of larger firms is discussed here because of their greater activity and visibility.

IBM's experience is one of the better-documented examples of the process. This firm is worth examining briefly because it was the dominant computer producer in the period. By the mid-1960s, its technologies and views about computer use predominated worldwide, even behind the Iron Curtain, underscoring America's durable significance in the field. IBM had product-development laboratories on the same campuses as its manufacturing plants, at which engineers and scientists could share information, which groups of foreign computer experts visited, and where clients were schooled in best practice. Teaching office-appliance customers for such early twentieth-century "high-tech" devices as Felt & Tarrant's calculators or Burroughs' adding machines was usual. Even earlier, typewriter manufacturers often worked with schools and other associations to offer skills classes, largely in North America and Europe.[52] In the 1950s and early 1960s, IBM essentially replaced a whole generation of electromechanical engineers and salesmen worldwide with new employees versed in electronics and computing (such as engineers in Poughkeepsie, New York, home of its mainframes) and with college graduates familiar

51. The subject of Cortada, *The Digital Flood*. The collection and sharing of information by vendors should not be confused with their actions with respect to their actual transfer and diffusion of technology. For a thoughtful discussion of this issue, see Mira Wilkins, "The Role of Private Business in the International Diffusion of Technology." Since patents are tied to information transfer, and purposefully not discussed in this paper, one can find a current discussion of its role by B. Zorina Khan, "Selling Ideas."

52. Cortada, *Before the Computer*, 18, 130, 269–70; Heide, *Punched-Card Systems and the Early Information Explosion* for extensive European examples.

with engineering and science for marketing in over two dozen countries.[53] Sales offices at IBM served as centers where customers were introduced to the newest technologies, and where they were taught how to use them, two processes that have continued to the present in 175 countries.

The practice of customers and vendor personnel meeting, learning, and talking together both in sales offices and at laboratories and manufacturing sites proved extensive and intense. There probably were few Fortune 1000 firms that did not regularly participate in this activity on a regular basis after the 1950s. The one massive exception was in Eastern Europe, behind the Iron Curtain, where marketing essentially did not operate, with a few minor exceptions, because government agencies directly developed, manufactured, and delivered computers, routinely with little or no adequate training or support. There engineers and scientists indeed debated the features of machines and software, but barely took into account feedback from actual users. The result was unsurprising: fewer installations of computers in Comecon countries than in capitalist economies.[54]

Where interactions occurred in noncommunist economies, often at events supported by ICL (British), Machines Bull (France), IBM, Amdahl, and Burroughs (United States) or others, thousands of customers and IT-industry personnel exchanged ideas. Engineers and scientists, vendors, and users showed up at each other's conferences and events, such as at the national and international computer societies noted earlier in this article. Again citing IBM, by the late 1960s the company had several hundred branch sales offices in over three dozen countries, and at least two dozen manufacturing plants and laboratories scattered across North America, Western Europe, and Asia. In Western Europe alone, IBM staffed a half-dozen laboratories with hundreds of employees, plus over a dozen manufacturing facilities, and over 150 sales offices, all interacting with each other, with clients and with agencies.[55]

Supporting this information ecosystem was a massive array of "gray" publications: nonpublic computer system materials that have not been studied.[56] Every computer product delivered since about 1950 was accompanied by several types of publications: technical descriptions of the equipment and software, user manuals instructing

53. Watson, Jr., *Father Son & Co.*, 241–2, 246, 346–52.

54. I discuss this in considerable detail in Cortada, *The Digital Flood*, 238–306.

55. IBM World Trade Corporation, *Annual Report 1969*, 24–5.

56. "Gray publications" refers to those that are not normally publicly available or conventionally accessible through libraries, for example. These can range from casual reports to massively detailed monographic publications rigorously adhering to academic standards. Examples include preprints and white papers.

operators and programmers on use protocols or instructing field engineers on how to repair equipment, alongside marketing materials and other publications for salesmen that cataloged product lines and described their features, still others describing potential uses of computing and why (e.g., for accounting, called *applications*), and thousands of short case studies of successful uses or fixes. The literature for a particular line of products could be voluminous, and was normally necessary for operations. For example, IBM's widely used System 360 computers of the 1960s to early 1970s arrived with over 50 linear feet of technical manuals.[57] During the 1960s–1980s, computer industry specialists considered IBM to be the world's largest publisher, exceeding the widely acknowledged and massive role played by the US Government Printing Office (GPO). By the 1980s over 20,000 IBM publications were in print. Collections of such gray materials make it clear that IBM was not an exception; all vendors published extensively and distributed far more copies of their publications than did commercial or academic publishers. Tens of thousands of government agencies, academic sites, and companies routinely received and used this literature.[58] One reason the Soviets standardized their computing technologies on IBM's System 360 was the availability of such a detailed body of explanatory literature that could more easily be translated into various languages than be written from scratch.[59] In many areas, then, this gray literature played a critical information ecosystem role.[60]

57. I was an IBM salesman in the 1970s, sales manager in the 1980s, and encountered these materials on a regular basis. Both the IBM Archives and the Charles Babbage Institute at the University of Minnesota, Minneapolis, have collections of these kinds of materials.

58. In addition to the large collections of such materials at IBM and CBI, there is a growing collection of some 10,000 items at the Computer History Museum at Mountain View, California, Sarah Wilson, "Guide to the Computer Collections of Computing Manuals and Marketing Materials," describes over 440 linear feet of materials.

59. Davis and Goodman, "The Soviet Bloc's Unified System of Computers," 93–122.

60. A question outside the scope of this article would be how computing's gray literature compared to that produced by "high-tech" companies in other domains, such as Boeing in aircraft manufacture. That literature is only just now being explored (yet not its business variants). But manufacturers of large complex equipment were extensive publishers of this kind of gray literature around the world. Indeed, it continues today even with simple consumer electronics such as digital cameras, kitchen appliances, and all of Apple's products. The same observation can be made about gray industrial films, describing products, including hundreds from IBM. Like grey literature, grey movies have hardly been studied. Films are normally available in corporate archives, such as at IBM's which has an excellent collection. Training films (a type of grey movie) once had their own journal covering worldwide developments, *Business Screen Magazine*, 1938–1976, discussing films from many industries, not just "high-tech" ones.

Nonprofit suppliers in the 1950s through the 1980s were overwhelmingly government agencies building computers in communist countries, IT-industry associations (such as the global Computer Society), royal institutes and other academies and institutes, particularly in Eastern Europe and in Asia, and lobbyist organizations in the West. The majority of the literature, their conferences, and other training programs, while crucial in disseminating information in the 1940s and 1950s, became less important by the 1960s when "user groups," (discussed subsequently in this article) came to the fore, along with their massive distribution of materials that they published and their hosting of training events by vendors.

Role of Customers and Other User Groups

Users—routinely referred to as customers—continuously played a proactive role in learning about computers, shaping their evolution, and supporting one another. They reworked practices that had long existed in other "high-tech" businesses, such as office appliances, aircraft, electrical utilities, and other science- and technology-based goods.[61] It seemed then, and for many decades afterward, that "everyone" learned from everyone else. Engineers were trying to figure out what customers could use and to persuade them to try new things; customers were explaining to vendors what they needed and the problems they were encountering; retail purchasers did the same in and after the 1990s with consumer electronics; and computer scientists consulted customers to see what issues to address, from making telecommunications work in the 1960s to dealing with software security issues today.[62] Customers served as positive references for a vendor's products, and shared their experiences with other users at conferences, through participation in case studies prepared by vendors and business schools, and in site visits. While these various activities await their historians, a very visible one can be described to suggest the further thickening of the early information infrastructure: user groups.

Within the first decade of commercial use, IT professionals and vendors formed what came to be called "user groups." Less formal than professional associations, their central function was to create channels for dispensing information about how best to use computing, how to overcome problems and quirks, and how to conduct

61. I am particularly influenced by the findings of Rogers, *Diffusion of Innovations*, Hippel, *Democratizing Innovation*.

62. Cortada, *The Computer in the United States*, 102–24.

https://doi.org/10.1093/es/kht095 Published online by Cambridge University Press

organized conversations with vendors about requirements and performance issues.[63] The primary mechanisms for such exchanges were annual national and regional meetings. Conventions in the United States, e.g., were major events—indeed often the largest in the world—with publication of proceedings and papers.[64] Associations organized local chapters with monthly meetings where vendors and users mingled and made presentations. This was widely done by the Data Processing Management Association (DPMA). Between 1973 and 1985, an annual US conference for all manner of vendors, consultants, and users was held, with attendance approaching 20,000 in some years, called the National Computer Conference (NCC), it too grew out of earlier assemblies dating to the early 1950s.[65]

The most common of these organizations were vendor specific, such as SHARE (not an acronym but a statement of its core mission, sharing) and GUIDE (Guidance of Users of Integrated Data-Processing Equipment) for IBM users, CUBE for Burroughs' customers, Joint Users Group (JUG), USE (for Univac organizations), and DECUS (Digital Equipment Computer Users Society) for DEC's users. Although largely self-organized international groups, vendors did play a crucial role in helping to fund and publish their proceedings, shaping agendas and, of course, providing speakers to insure that their points of view on products and uses were available. Key topics discussed at these conferences included various managerial issues relevant to computing's management, such as databases, security, managing high-tech work forces, software and application development, and persuading non-IT management about computing's benefits.[66] Historians investigating some of these associations are uncovering a substantial body of material about computing, while revealing these extensive knowledge-sharing activities.[67]

In addition to being one of the largest organizations, GUIDE provides useful insights regarding an important institution yet awaiting its historian. Briefly put, it is the longest-lasting group of IBM users in the world. Representatives from 44 companies founded GUIDE

63. Thomas Haigh in a series of studies explored these issues, "Sources for ACM History: What, When, Why"; and "Inventing Information Systems"; but see also, Nathan Ensmenger, "Power to the People," 94–96; and his "Letting the 'Computer Boys' Take Over"; also, A. Akera, "Voluntarism and the Fruits of Collaboration."

64. A paper trail of proceedings and other documentation of such meetings is beginning to accumulate. One of the best collections of such ephemera can be found at CBI, where, e.g., there is a large collection of SHARE publications, CBI Record Group 21.

65. Korzenoiwoski, "NCC Past to Present: A Barometer of Industry Progress," 8.

66. Cortada, *The Digital Hand*, vols. 1–3.

67. Haigh, "A Veritable Bucket of Facts," 33–49 and his "Sources for ACM History," 36–41.

in 1956 to exchange experiences using IBM's computers. In 1970 it formally became the nonprofit GUIDE International Corporation. A decade later, it claimed a membership of some 2,400 firms and government agencies. For an organization to join, it had to have installed a mid-sized or larger IBM computer, leading GUIDE's focus to the technical issues for large mainframe computing.[68] Like SHARE and some other dozen user groups of this type, it promoted professionalized operations and established an extensive network among members (including IBM's product developers and scientists). GUIDE committees and task forces assessed needs, communicated with IBM, documented best practices, and developed training sessions. Over time it embraced a fourth mission: to influence public opinion about the role of computers in society. It held typically two annual conferences and, by the mid-1980s, over 4,000 attendees participated, often choosing among over 150 events at each convention. Like the DPMA and other associations, GUIDE had chapters in other advanced economies where computing was widely deployed.[69]

SHARE played a similar role and was the first group created for computer users. Early in the 1950s, IBM engineering and product managers brought customers together to discuss their machines, their experiences, and their needs, in addition to visiting individual clients. In 1954 a group of users met in Los Angeles to expand discussions, which generated a project to develop software to further optimize IBM's machines. In 1955 IBM hosted a Los Angeles conference about its 704 system, and soon after 22 firms formed SHARE. A quarter century later, over 1,500 organizations belonged, making SHARE one of the largest such user groups in any industry globally.[70] It launched projects to improve software, educate, and serve up advice to IBM. Members created committees to address technical and managerial issues, sustaining these for as long as was needed and, as a byproduct, sponsored educational events and publications, including proceedings. DPMA and GUIDE did the same, among others. SHARE members favored scientific and engineering uses of computing, while GUIDE focused more frequently on businesses' informational needs.

These organizations proved successful for several reasons. First, as with many newly emerging technologies, the most useful and earliest available sources of information were vendors and users. Best practices, academic training, and textbooks only began to proliferate after the mid-1950s, a years-long lag still in evidence today. A fast way to share information, then, was by vendor-user conversations and

68. Akera, "Voluntarism and the Fruits of Collaboration: The IBM User Group, Share," 710–736.

69. O'Leary, Jr., "GUIDE," 670–1.

70. Armer, "SHARE—A Eulogy to Cooperative Effort," 122–9.

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dialogues between customer organizations and their user employees. Second, user groups generally provided a sound mechanism for communicating product requirements and problems to a vendor, who also learned what was needed next, with a high level of confidence about the information exchanges. Third, the 1940s' practice of groups of engineers, vendors, and users traveling from one locale to another proved slow and expensive, although effective and popular. This worked well when there were only a few score computer installations in the West and similar clusters in Eastern Europe or Asia. But that way of communicating proved far too inefficient as the industry expanded dramatically, and user groups took its place.

An additional set of groups participating in computing's information ecosystem, which can only be mentioned here, was the industry association. Formed largely first in the United States and later in other countries, these organizations enlisted member companies and individuals within an industry, such as banks and bankers in the American Banking Association (ABA). Covering all manner of issues and educating members on all manner of topics, they included computing as one theme. The ABA informed members about IT trends, how best to use computing, who was doing what with computers, and why. Its weekly or monthly newsletters and industry magazines, such as *ABA Banking Journal* published case studies and surveys.[71] Many associations held national conferences, published proceedings, sometimes just on computing.[72] Hundreds of these associations operated in the United States alone during the 1940s–1960s, and almost all enthusiastically promoted computing and its predecessor technologies, beginning in the 1910s and expanding dramatically in the 1920s and 1930s. Their records, proceedings, trade magazines, and publications, represent a massive body of material that has hardly been used, is often difficult to find, and is almost always poorly or not at all indexed. Extant materials are difficult to consult because they were available only to members and a few libraries; most discarded their copies, much the way people dispose of yesterday's newspaper.[73]

Examining the American experience with these and other computer organizations is made possible by the developing collections of materials at such repositories as university libraries, some at the

71. I discuss the ABA and its industry in more detail in Cortada *The Digital Hand*, vol. 2, 37–112.

72. For example, Life Office Management Association (LOMA) in the insurance industry, from 1959 to the end of the 1980s, Ibid., 586.

73. I personally was able to write a three-volume history of how computing was used in 36 industries largely on the back of that class of literature, but only after patiently turning thousands of pages by hand to understand issues and events covering a half century of computing and industry news. See Cortada, *The Digital Hand*.

organizations themselves, and at major corporate archives and libraries.[74] Less clear is the survival of such collections in Europe and Asia, although it is becoming increasingly evident that these existed, either through international chapters of the American associations, or through the participation of individuals at American events. Smaller, less-formal networks appeared in all countries that had become users by the end of the 1960s, most notably in Eastern Europe and India, through chapters of the Computer Society and other Western institutions.[75] As yet, scholars have yet to study these associations to any notable degree.

A final group of players are computing industry consultants and information providers, such as the publishers of *ComputerWorld* and *Datamation*, and specialized reports, such as those from IDG, Gartner and Input in later years. These organizations generally did not come into existence until the late 1950s to early 1960s, and historians are only just now beginning to examine their activities. Most consultancies in the 1940s–1950s did not specialize in computing; they merely added that capability onto their repertoire of offerings as clients required them. Early participants included McKinsey & Company, Arthur Anderson & Company, and Frost & Sullivan, all three essentially American firms with overseas offices. They advised on acquisitions and also implemented them for clients, participating as well in user groups such as those discussed earlier in the text.[76]

Role of Large Organizations: Government, Academic, Private Sector

Central to any understanding about the diffusion of information about IT and its use are large enterprises, which have already been much studied.[77] As large agencies and businesses emerged, they acquired and used all the major tools developed to collect, manage,

74. The largest collection of these IT-centered materials are located at the Charles Babbage Institute, University of Minnesota, Minneapolis.

75. Majumder, "Thoughts on Emergence of IT Activities in India," 4–7.

76. The key work today on that community is by Christopher D. McKenna, *The World's Newest Profession.* The leading student of the IT specific consultancies is Jeffery Yost, who is currently completing a book-length study of these firms. A large collection of the studies prepared by these consultancies is available at the archives of the Charles Babbage Institute, University of Minnesota, Twin Cities.

77. On economics see eight essays with extensive discussions of literature in Quah, "The Knowledge Economy and ICTs," 34–219; on business and government, Chandler, Jr., *Inventing the Electronic Century*; Cortada, *The Digital Hand*, 3 vols; Agar, *The Government Machine*; Impagliazzo, Lundin, and Wangler, *History of Nordic Computing*; Coopey, *Information Technology Policy*; Johnson, *MITI and the Japanese Miracle*; Dedrick and Kramer, *Asia's Computer Challenge*.

and use information in order to control their operations in productive ways. These included electronic communications (e.g., telegraph, telephone), adding and calculating machines, and files and paper record-keeping practices and library systems.[78] As a by-product of their experiences with these information-handling technologies, these organizations developed a deep appreciation for IT's value, an understanding that made it possible to determine quickly whether a new information technology had practical possibilities. That realization required their employees to constantly keep up with changes in IT, indeed to develop them on their own or in collaboration with vendors. This happened in the United States, in Western Europe, and later in Asia, as thousands of firms worked with multinational computer vendors and scores of other product developers.[79]

This also occurred in Europe's largest industrializing economies, such as Germany, Austria, Sweden, The Netherlands, Britain, Poland, and less so in less-industrialized ones, notably France, Italy, and the USSR, beginning with punch-card tabulating equipment everywhere.[80] Asian enterprises did not track information technology innovations until their economies underwent broad industrialization, beginning largely in the 1950s in Japan and in the late 1970s across nearly a dozen other countries.[81] Users of punch-card equipment during the 1920s–1950s became early users of digital computers. Often members of their staffs were involved in the collection and sharing of information about computing. They had worked earlier in large companies, government agencies, and universities with strong commitments to engineering and science. This pattern continued in emerging economies too, where, e.g., Indian and Chinese national government agencies, the best-established universities, and commercial enterprises acquired knowledge and showed significant interest late in the twentieth century, despite isolated instances of early information sharing in the 1950s and 1960s.[82]

The primary reasons for large organizations' deep engagement derived from two circumstances: war and cost. During much of the

78. Beniger, *The Control Revolution*; Cortada, *Before the Computer*, Yates, *Control Through Communication*, Chandler, Jr., *The Visible Hand*.

79. Cortada, *The Computer in the United States*; Flamm, *Creating the Computer* and *Targeting the Computer*.

80. Heide, *Punched-Card Systems and the Early Information Explosion*; Cortada, *The Digital Flood*, 91–237.

81. Hanna, Boyson, and Gunaratne, *The East Asian Miracle and Information Technology;* Morris, *Why the West Rules—For Now*, 557–622; Hachigian and Wu, *The Information Revolution in Asia*; Deyo, *The Political Economy of the New Asian Industrialism*; Dedrick and Kraemer, *Asia's Computer Challenge*, 252–3.

82. I explain these developments in considerable detail in Cortada, *The Digital Flood*, 375–570.

past 150 years, industrialized economies were involved in warfare of one sort or another.[83] In the nineteenth century this largely meant colonization or conquest in the western United States, Australia, all of Africa, the Middle East, and major portions of Asia, increasing requirements for the rapid movement of information for purposes of control, along with people and goods for reasons of emigration and trade.[84] Then World War I, various regional and civil wars, World War II, and the security and intelligence requirements of the long Cold War and its proxy wars enhanced information technology's significance.[85] Histories of computing are generally quite detailed about British and American experiences, but scholars are increasingly learning about the extensive activities of the Soviets, other European nations, and most recently, the emerging Indian and Chinese military interest in computing.[86] From satellites to GPS systems, from radio to radar, operations research to Big Data, from artillery firing tables to the Internet itself, the exigencies of warfare drove innovations and the continuous hunt for information about computing.[87] Chinese and American defense agencies remain some of the world's largest IT developers.

Costs of computing proved crucial too. Computers were very expensive, indeed so much so that only the largest organizations could either afford the outlays required or had extensive activities that could be improved sufficiently to justify these massive expenditures. Governments chiefly funded the earliest R&D projects (1940s-1960s), and still do in many instances, with large corporations following in the 1950s, many initially for military purposes with civilian uses following.[88] Economists studying the technology's cost to institutions and whole national economies, have established that whereas it declined sharply between 1950 and 2000, it nonetheless

83. For a shocking list of the wars in chronological order just covering the nineteenth century, Rosenberg, *A World Connecting*, pp. 109–110. Warfare in the twentieth century cost many tens of millions of more lives than in the nineteenth, made possible by myriad technologies, not just more lethal weapons, and existed in every year of that century.

84. Thoroughly discussed by Headrick, *The Tools of Empire* and in *Invisible Weapon*; but see a sweeping analysis by Ballantyne and Burton, "Empires and the Reach of the Global," 285–431.

85. Flamm, *Targeting the Computer*, Edwards, *The Closed World*.

86. I provide an extensive bibliography of this literature in Cortada, *The Digital Flood*, 733–68.

87. The most compelling case is made by Edwards, *The Closed World*, and Flamm, *Targeting the Computer*. But the literature is now vast.

88. The best documented experiences are American; for an example of this literature covering many of the key issues, see Redmond and Smith, *Project Whirlwind*, and its sequel, *From Whirlwind to Mitre*; for Swedish, Geer, *På väg till datasamhället* and an earlier study covering more years, by Lindkvist, *Dataeknik och politik*, for Eastern European developments, Wilczynski, *Technology in Comecon*.

remained high. A supercomputer from IBM today still costs millions of dollars and those used by organizations such as Sony, Tata, University of Paris, Wells Fargo Bank, and universities still cost close to 1 million dollars, not counting the necessary software and peripheral equipment.[89] Only when vendors began to make smaller computational products, built with less-expensive components whose cost also declined, in cost, did the relative cost to an organization decline. For example, this opened the way to minicomputers being acquired by smaller companies, schools, and agencies in the West in the 1960s and 1970s, PCs by many large, mid-sized, and even smaller ones, beginning in the 1980s across the Western world, and in industrializing Asian nations, and most recently, mobile phones with PC functions in Africa and Latin America.[90] In short, the needs of large institutions led their managements to supply money and personnel to search for IT information and to share it in exchange with one another or as a means to integrate smaller suppliers into global supply chains.

Conclusions and Implications

Information ecosystems are increasingly drawing the attention of historians who recognize that these comprise important, if nearly invisible organizational infrastructures.[91] As argued earlier in this article, their role should be considered when studying the evolution of firms, industries (and their associations), technologies, even whole economies. It appears that at least two global information ecosystems emerged, each facilitating the flow of information about computing within their spheres of influence, but also borrowing knowledge from the other. The first involved largely the Atlantic community—North America and Western Europe—with Asia later participating, most notably Japan, ca. 1950–1975. This information ecosystem was largely dominated in all its facets by the United States. A second information ecosystem, hosted by the Soviet Union, and although less well understood historically, was clearly also quite large, and included a limited participation by China and India. It too generated and diffused information about computing, but also borrowed heavily from the Western information ecosystem. Then, of course, within nations, rarely regions, there were smaller circles of experts and their supporters who were interested in learning about computing.

89. For a useful introduction on the issue of costs relevant for the period, Sichel, *The Computer Revolution.*

90. Dedrick and Kraemer, *Asia's Computer Challenge.*

91. Recently two journals have changed their mission and title to reflect this new emphasis, *Information and Culture: A Journal of History* and *Library and Information History.*

The expanded interest in global history offers new ways to examine the history of business, economics, and technology by studying knowledge transfers. Historians are aware that computing was a global development, an international industry, with transnational business and public-sector users, and that it proved to be a technology highly resistant to political, economic, or linguistic barriers and able to evolve, and thus was adopted around the world. Of course, the prospect of dealing with multiple languages, doing research in numerous countries, understanding multiple businesses, social, and legal contexts is daunting. One should not suggest otherwise; but information ecosystems do represent sources of data available for study. Indeed English was widely used by the protagonists, while large repositories of research materials that cross nations and eras have become available, such as at the University of Minnesota's Charles Babbage Institute and at various other universities, associations, and government agencies.[92] Ultimately, the business history of computing is a global story that historians need to examine comprehensively.[93]

This finding for computing is consistent with what historians of business and technologies have been discovering over the past several decades for many other activities.[94] That the computing community was large and international also suggests that the history of modern business enterprises, industries, indeed whole economies, needs to take account of computing, and as a by-product, the agents and agencies that facilitated its uses since World War II. An additional finding was how early, and also, how quickly, this information ecosystem and the transfer of knowledge took place. Many users and developers of new objects and supporting institutions were forming before they became public or evident. Tied to that is the additional observation that activities sprouted in far more places than one might initially assume. While writing a global history of IT, I uncovered interest in computing in the 1950s in many less obvious places, such as in Tibet, Egypt, Cuba, and South Africa, none of which has been yet explored by historians.[95]

92. One massive source of information about computing not known to many historians, because it has come online only in the past few years is a series of databases created by the IT History Society, which serve as a "gear box" pointing people to archives and other sources. The archival references, alone, point to over 15 million pages of materials, a treasure to be discovered by historians. See, http://www.ithistory.org (last accessed June 15, 2013).

93. Discussed more fully in Cortada, "How New Technologies Spread: Lessons from Computing Technologies."

94. Particularly useful on this point, see Chandler and Mazlish, *Leviathans*, but see also the massive collection of essays in Rugman, *The Oxford Handbook of International Business.*

95. Cortada, *The Digital Flood*.

One explicit implication is that computing enhanced globalization in general, although not until after 1970. In that decade, one can observe the start of a sharp rise in sociologists' and economists' interest in how computing was affecting societies, perhaps a phenomenon as important as the interest evinced by engineers and early computer scientists, as discussed earlier in this article.[96] Of course, examining the global diffusion of IT begs for more questions to be answered, such as, how did that experience compare to those of other technologies? What effects did all the fact-finding cases discussed here have on a company's or industry's ability to shape technologies and their products? Put another way, what were the possible additional dynamics driving information seeking by engineers and scientists, business employees, the military, and public officials? Exciting research lies ahead, for certain.

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96. The one major exception came from France where one book critical of American business intrusions, including those by IBM and other American computer vendors, into the French economy led to a nearly 20-year debate about information societies in France, and to the same debate across Europe, which continues to this day, Jean Jacques Servan-Schreiber, *Le Défi Américain*. One major American commentator on the subject published at the end of this period and proved more influential in the 1970s, rather than in the 1960s, Alvin Toffler, *Future Shock*.

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