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About the cover: *Clad in the conservative garb of Quakerism—cap, kerchief, and dark gown—American social reformer Lucretia Mott (1793-1880) presents a regal image in this daguerreotype portrait. This view of the daguerreotype, which was taken circa 1850-1855 (photographer unknown), shows the deterioration at the edges of the metal plate. To explore some of the reasons for daguerreotype degradation, see the book review on page 380 of* The Daguerreotype: Nineteenth-Century Technology and Modern Science. *Photograph courtesy of Chicago Historical Society, copy neg. ICHi-11897.*

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Research Article

Scholarly Communication and Information Technology: Exploring the Impact of Changes in the Research Process on Archives

AVRA MICHELSON AND JEFF ROTHENBERG

About the authors: *Avra Michelson is a member of the Technology Research Staff at the National Archives and Records Administration. Jeff Rothenberg is a Senior Computer Scientist in the Social Policy Department of The RAND Corporation.*

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EXECUTIVE SUMMARY

The emergence and use of information technology is this century's most significant development affecting archival practice. In response to this development, members of the archival profession have explored both the ways in which new technology can improve the management of archives, and the most appropriate methods for managing electronic records that result from the use of automated systems. But these two issues only partially address the impact of technology on archives. A third but indirect influence also deserves examination: technology's impact on scholarly research methods, which has consequences for the use and management of archives. This article considers the policy implications for archives of trends resulting from the infusion of information technology into the scholarly research process.

The article considers the interaction of two distinct kinds of trends: trends in information technology and trends in research practices, particularly among social scientists and humanists. Although much of the rapid growth and evolution of information technology may be unrelated to scholarly research, and aspects of scholarly research may be evolving in ways that have little connection with information technology, there is nevertheless a strong and important interaction occurring between these two evolutions. The possibilities created by

new technology are prompting transformations in scholarly practice, and these transformations are in turn stimulating new needs among researchers and are inspiring further technological breakthroughs. Understanding the nature of this interaction is necessary for forecasting the most likely ways in which new scholarly methods will demand innovative services and responses from the archival community.

This article explores two fundamental trends in information technology affecting scholarship: end-user computing and connectivity. Several other technologies of relevance to scholarship are also considered, including artificial intelligence, end-user publication and distribution, hypertext and hypermedia, and visualization and virtual reality. Changes in the research process resulting from scholarly use of information technology are considered within the broad framework of scholarly communication. The scholar's use of currently available technology to search for sources, communicate with colleagues, interpret and analyze source materials, disseminate research findings, and prepare curriculums and instructional applications is examined. Our key finding is the exploding use among researchers of information technology on research and education networks to advance scholarship. Far from being visionary, this future is already present: It is currently being experienced by significant and increasing numbers of scholars from many disciplines. The library profession is responding to the emergence of network-mediated scholarship by promoting global connectivity, performing conversions of print sources to machine-readable form, undertaking the software engineering of full-text delivery systems for online materials, and collaborating with technologists in the use of computing and communication technology to meet specialized researcher needs.

The report recommends that the archival profession:

1. establish a presence on the Internet/NREN.
2. make source materials available for research use over the Internet.
3. create documentation strategies to document network-mediated scholarship and the development of research and education networks.
4. develop archival methods suitable for operation with NREN.
5. take user methods and future computational capacity into account in establishing policies on the management of software-dependent records.
6. recognize and reward initiatives that (a) advance archival management of electronic records, (b) respond to scholarly use of information technology, or (c) promote a network-mediated archival practice.

This article is the result of nearly two years of collaboration between Avra Michelson and Jeff Rothenberg. Earlier versions or derivative presentations of the article were reported at annual meetings of the Society of American Archivists, National Association of Government Archivists and Records Administrators (NAGARA), National Net '92, and the Library of Congress Workshop on Electronic Texts. The article is available electronically on the file server operated by the Coalition for Networked Information. (Contact craig@chi.org for instructions.)

INTRODUCTION

The emergence and use of information technology is this century's most significant development affecting archival practice.[1] In response to this development,

[1]The term *archives* refers broadly to historic sources of enduring value that document the activities of governments, organizations, or individuals; it also refers to the repositories responsible for preserving and making available the historic record.

members of the archival profession have explored both the ways in which new technology can improve the management of archives[2] and the most appropriate methods for managing electronic records that result from the use of automated systems.[3] But these two issues address only a portion of the impact of technology on archives. A third though indirect influence that deserves examination is technology's impact on scholarly research methods, which has consequences for the use and management of archives. This article considers the policy implications for archives of trends resulting from the infusion of information technology into the scholarly research process.

The term *information technology* refers to the computing and communications technology used to obtain, store, organize, manipulate, and exchange information. The definition includes computer hardware and software, as well as the telecommunications devices and computer-based networks that connect them.[4] The influence of information technology on the research process, already evident, promises to deeply penetrate scholarly practice as we enter the twenty-first century. This technology is enabling academics to change significantly the way they communicate and collaborate, identify and analyze sources, store and retrieve data, and disseminate the products of their research. Although technology affects the research process across a spectrum of disciplines and professions, this article focuses on changes in the social sciences

[2]See Marion Matters, ed., *Automated Records and Techniques in Archives: A Resource Directory* (Chicago: Society of American Archivists, 1990), 12–37, for a bibliography on the topic. A selection of the seminal literature includes: Thomas H. Hickerson, *Archives and Manuscripts: An Introduction to Automated Access,* SAA Basic Manual Series (Chicago: Society of American Archivists, 1981); Richard H. Lytle, "An Analysis of the Work of the National Information Systems Task Force," *American Archivist* 47 (Fall 1984): 357–65 (see also other articles in this issue of *AA*, especially Thomas E. Brown, "The Society of American Archivists Confronts the Computer," pp. 366–82); David Bearman, *Towards National Information Systems for Archives and Manuscript Repositories: The NISTF Papers* (Chicago: Society of American Archivists, 1987), as well as Bearman's *Archives and Museum Informatics* technical reports and quarterly newsletter; and two special issues of the *American Archivist* devoted to "Standards for Archival Description" (Fall 1989 and Winter 1990). More recently, archivists have begun to explore the use of specific technologies to support archival functions. See, for instance: *Optical Digital Image Storage System: Project Report* (Washington, D.C.: National Archives and Records Administration, Archival Research and Evaluation Staff, March 1991); Avra Michelson, *Expert Systems Technology and Its Implications for Archives,* National Archives Technical Information Paper no. 9 (Washington, D.C.: National Archives and Records Administration, Archival Research and Evaluation Staff, March 1991); and Anne R. Kenney and Lynne K. Personius, "The Future of Digital Preservation," *Advances in Preservation and Access*, vol. 1 (Westport, Conn.: Meckler Press, forthcoming).

[3]Charles Dollar identifies salient literature on this topic in his work, *The Impact of Information Technologies on Archival Principles and Methods* (Macerata, Italy: University of Macerata Press, 1992). A selection of seminal publications includes: Charles Dollar, "Appraising Machine-Readable Records," in *A Modern Archives Reader: Basic Readings on Archival Theory and Practice*, edited by Maygene F. Daniels and Timothy Walch (Washington, D.C.: National Archives and Records Service, 1984); Margaret L. Hedstrom, *Archives and Manuscripts: Machine-Readable Records*, SAA Basic Manual Series (Chicago: Society of American Archivists, 1984); Harold Naugler, *The Archival Appraisal of Machine-Readable Records: A RAMP Study with Guidelines* (Paris: General Information Programme and UNISIST, UNESCO, 1984); United Nations, Administrative Committee for the Coordination of Information Systems, Technical Panel on Records Management, *Electronic Records Guidelines: A Manual for Policy Development* (New York: United Nations, 1989); and *Research Issues in Electronic Records.* (St. Paul, Minn.: Published for the National Historical Publications and Records Commission, Washington, D.C., by the Minnesota Historical Society, 1991). See also Tom Ruller, "Managing and Appraising GIS Data: Issues and Strategies," unpublished paper presented at the 1991 annual meeting of the Society of American Archivists, Philadelphia.

[4]John R. B. Clement, "Increasing Research Productivity Through Information Technology: A User-Centered Viewpoint," unpublished paper, 19 October 1989, p. 3.

and humanities because scholarly patrons of archives tend to be drawn most heavily from these fields.[5]

Undertaking the research for this report was motivated, in part, by efforts in the archival profession to provide answers to questions related to the use of source materials, such as the following: Who are the (potential) users of primary sources? What are the characteristics of the modern research process? How do patrons frame research questions?[6] In the past few years, several empirical studies have been conducted on patterns of research use within or across repositories or specific disciplines.[7] Although these studies provide valuable insights on users and patterns of use for the period of study, they typically fail to consider their findings within the context of a broader analysis of scholarly research trends.

Archivists need more than snapshots as a basis for policy formulation. An accurate depiction of current research practices is necessary, but archival strategic planning must also involve an analysis of significant trends. This article addresses the interaction of two distinct sets of trends. Electronic information technology as a phenomenon is experiencing rapid growth and evolution, much of which may be unrelated to scholarly research. At the same time, aspects of scholarly research may be evolving in ways that have little connection with information technology. Nevertheless, a strong and important interaction is occurring between these two movements. The possibilities created by new technology are prompting transformations in scholarly practice, and these transformations are in turn stimulating new needs among researchers and further inspiring technological breakthroughs. Understanding the nature of this interaction is necessary for forecasting the most likely ways in which new scholarly methods will demand innovative services and responses from the archival community.

Trends analysis is inherently somewhat circular, since technological changes "drive" changes in scholarly practice only to the extent that the new technology provides capabilities that scholarly researchers can use in meaningful and productive ways. It involves more than the description of arbitrary technological trends: Their relevance must be derived from the perspective of scholarly research. It also involves more than the description of current trends in scholarship: To the extent that scholarship uses information technology, it is necessarily constrained by what is currently possible. Only by considering the joint evolution of technology and scholarly methods can a

[5]The terms *scholar* and *researcher* generally are used throughout the paper to refer to social scientists and humanists unless specified otherwise. Nevertheless, we believe that the research trends identified in this report apply to a broader range of the research community.

[6]A selection of key literature that has advanced the archival profession's conceptual framework includes: Mary Jo Pugh, "The Illusion of Omniscience: Subject Access and the Reference Archivist," *American Archivist* 45 (Winter 1982): 33–44; Elsie T. Freeman, "In the Eye of the Beholder: Archives Administration from the User's Point of View," *American Archivist* 47 (Spring 1984): 111–23; Paul Conway, "Facts and Frameworks: An Approach to Studying the Users of Archives," *American Archivist* 49 (Fall 1986): 393–407; and Lawrence Dowler, "Availability and Use of Records: A Research Agenda," *American Archivist* 51 (Winter/Spring 1988): 74–86.

[7]A selection of the key studies includes: *Major Findings, Conclusions and Recommendations of the Researcher and Public Service Component Evaluation Study* (Ottawa: Public Archives of Canada, 1985); Paul Conway, "Research in Presidential Libraries: A User Study," *Midwestern Archivist* 11 (1986): 35–56; William J. Maher, "The Use of User Studies," *Midwestern Archivist* 11 (1986): 15–26; David Bearman, "User Presentation Language in Archives, *Archives and Museum Informatics* 3 (Winter 1989–90): 3–7; Paul Conway, *Partners in Research: Towards Enhanced Access to the Nation's Archives* (Washington, D.C.: National Archives and Records Administration, forthcoming); and Ann D. Gordon, *Using the Nation's Documentary Heritage: The Report of the Historical Documents Study*, supported by the National Historical Publications and Records Commission in cooperation with the American Council of Learned Societies (Washington, D.C.: National Historical Publications and Records Commission, 1992).

convincing picture of the future be constructed. The remainder of this article attempts to create such a picture in order to examine its implications for archives during this decade and beyond the turn of the millennium.[8]

This article presents a conceptual framework for understanding long-term trends relevant to the scholarly research process. The topic is introduced by a discussion of scholarly communication and the early use of computers among academics. An analysis of information technology trends most pertinent to the conduct of research follows. The third section explores, through case examples, trends in the use of currently available information technology by social scientists and humanists. The fourth section considers model efforts by those in the library profession to respond to changes in the research process. The article concludes with policy recommendations that address key changes needed in archival practices and methods to respond to transformations in scholarly research methods, and the growing prominence of a new electronic communication medium—research and education networks.

BACKGROUND

Scholarly inquiry represents a timeless human quest to understand the world around us. Although this quest for understanding is a sustaining element of human culture, the techniques of the scholar have changed over time. No longer characterized by oral tradition and forum dialogues, the modern research process is commonly understood to entail five processes: (1) identification of sources, (2) communication with colleagues, (3) interpretation and analysis of data, (4) dissemination of research findings, and (5) curriculum development and instruction for preparing the next generation of scholars. Refinement of the scholar's original idea or hypothesis occurs throughout these more tangible processes. The impact of information technology on these processes is resulting in unprecedented transformations in scholarly communication.

Scholarly communication is the term used to refer to the interrelationship of the five processes of modern scholarship.[9] The term implies both a dynamic exchange of information and ideas and an interdependence among publishers, librarians and others in the support of scholarship and the advancement of knowledge. Scholarly communication is generally understood to involve the social exchange of intellectual and creative activity from one scholar to another.[10] As a concept, it denotes a recognition of the mutual reliance of researchers, publishers, professional associations, and libraries and archives in fostering intellectual pur-

[8]Because this paper examines the interaction of two distinct trends, differing frameworks are used to organize the key sections (Overview of Information Technology Trends and Scholarly Communication and the Use of Current Information Technology). The former uses information technology trends as the organizing framework, whereas the latter uses the elements of scholarly communication as a structuring framework. The relationship between technology and scholarship is both dynamic and complex, and our understanding of it continues to evolve. Although it was suggested to us that the framework used to explore information technology trends should be used as the organizing framework for the section on current scholarly practices as well (e.g., a more technological determinist approach), we consider the dual frameworks, and the analysis of the relationships between them, one of the paper's key virtues.

[9]The American Council of Learned Societies popularized the term *scholarly communication* among academics as a result of their mid-1980s survey on the experience of more than five thousand humanists as authors using scholarly publications, libraries, and computers. The findings of the report appear in Herbert C. Morton and Anne J. Price, *The ACLS Survey of Scholars: Final Report of Views on Publications, Computers, and Libraries* (Washington, D.C.: Office of Scholarly Communication and Technology, American Council of Learned Societies, 1989).

[10]Thomas W. Shaughnessy, "Scholarly Communication: The Need for an Agenda for Action—A Symposium," *Journal of Academic Librarianship* 15 (May 1989): 69.

suits. This interdependence implies that a change in the practice of any one of these agents is capable of inspiring changes in the entire paradigm. In transforming the way in which academics learn of primary source materials, search and gather data, interpret and analyze sources, and report findings to the scholarly community, information technology is influencing significant aspects of scholarly communication. Consequently, changes in scholarly research patterns have ramifications for archives and libraries.[11]

The influence of modern technology on scholarly communication began with the birth of computers. More than forty years ago, the scientific community was the first of the academic disciplines to introduce computers into the research process. As computing power expanded, geographically dispersed scientists began collaborating on research questions requiring computers. In 1969, in response to the needs of this community, the U.S. Defense Department's Advanced Research Projects Agency (ARPA) developed the ARPANET, a telecommunications network designed to allow the sharing of expensive computer resources among government and academic research laboratories.[12] Scientific computing has evolved to include the use of electronic networks for electronic mail (e-mail) and for access to supercomputing processing power and to software that facilitates group work.[13]

Since the 1970s, a large and complex array of networks has emerged to support collaborative scientific research. As the scientific need for connectivity increased, network infrastructures at institutions, organizations, commercial enterprises and regions expanded. Today, more than three thousand regional, federal, commercial, and organizational networks connect an estimated 5 million scholars in seventy countries.[14] The Internet, the existing network of research and education networks, comprises thousands of trunk lines that currently carry from 1.5 to 45 million bits per second.[15] The National Research and Education Network (NREN), authorized in 1991 and due to be operational by 1995, will be capable of transmitting 1 billion bits of data—the equivalent of fifty thousand typewritten pages—every second.[16]

In recent years, the global expansion of electronic networks has allowed for worldwide collaboration among scientists. Further, the connectivity provided by greater bandwidth lets scientists process previously unimaginable amounts of data. Expanding the volume of data able to travel across networks permits scientists to explore new types of questions because greater amounts of data are available with less time required for analysis. Equally important, the prom-

[11]For a historical consideration of the relationship between scholarly communication and libraries, see Phyllis Dain and John C. Cole, eds., *Libraries and Scholarly Communication in the United States: The Historical Dimension,* Beta Phi Mu Monograph, no. 2 (New York: Greenwood Press, 1990).

[12]Clifford A. Lynch and Cecilia M. Preston, "Evolution of Networked Information Resources," *Proceedings of the Twelfth National Online Meeting May 7–9, 1991 N.Y., N.Y.,* Martha E. Williams, ed. (Medford, N.J.: Learned Information, 1991): 221–30.

[13]See, for instance, a recent book of readings, edited by Irene Greif, *Computer-Supported Cooperative Work* (San Mateo, Calif.: Morgan Kaufmann, 1988); for an assessment of the information needs of the scientific scholar, see *Communications in Support of Science and Engineering: A Report to the National Science Foundation from the Council on Library Resources* (Washington, D.C.: The Council, August 1990); for a discussion of state-of-the-art collaboration-oriented software, see Daniel Williams, "New Technologies for Coordinating Work," *Datamation* 36 (15 May 1990): 92–96.

[14]Clifford Lynch, "Telecommunications and Networking: A Tutorial," presentation made at the American Society for Information Science 54th Annual Meeting, Washington, D.C. (29 October 1991).

[15]Lynch and Preston, "Evolution of Networked Information Resources."

[16]From a presentation by Paul Peters, executive director of the Coalition for Networked Information, to the National Archives and Records Administration on 7 May 1991; see also Ralph Alberico, "The Development of an 'Information Superhighway'," *Computers in Libraries* 10 (January 1990): 34.

ise of increased computing power and advances in telecommunications will allow scientists to expand the graphical display of research results, alleviating many problems associated with interpreting very large data sets.[17] The trends characteristic of modern scientific inquiry—greater collaboration, increased use of computer-assisted analysis of machine-readable sources, and expanded use of global research and education networks—increasingly represent trends in the social sciences and humanities as well.

In the humanities, scholars initially used computers simply to store and retrieve data. In what is commonly believed to be the earliest project of its kind, Father Roberto Busa in 1949 began his effort to compile an index and concordance to the work of St. Thomas Aquinas.[18] But apart from the hard sciences, the field of political science is typically regarded as the discipline most responsible for transforming computer processing into an accepted scholarly method. What began as a simple use of computers by political scientists for processing survey data and analyzing national opinion polls became a standard social science methodology: quantitative analysis. During the past four decades, following the lead of survey researchers, a range of scholars within academic disciplines began to use computer technology to process large sets of numeric data.[19]

The advance of information technology over the past several decades has astonished even the most visionary technologists. Although certain predictions have proved too optimistic, the overall rate of advance has matched or surpassed the prophesies of most experts, and it shows every sign of continuing unabated during the next few decades. Indeed, from 1980 to 1985, the period that marked the birth of personal computers, their use among scholars soared from nonexistent to more than 50 percent.[20] Today, the scholarly use of personal computers extends beyond storage and retrieval of data and includes text editing, formatting, and text analysis. Increasingly scholars are turning to technology to do statistical analysis, create databases, produce spreadsheets, and compile graphical images of data. Many scholars consider technology an essential instructional tool for generating simulations, capturing data, and

[17]Clement, "Increasing Research Productivity," 3; for a discussion of the role of imagery in human understanding, see Mary Alice White, "Imagery in Multimedia," *Multimedia Review* (Fall 1990): 5–8.

[18]See David S. Miall, ed., *Humanities and the Computer: New Directions* (Oxford: Clarendon Press, 1990), 2.

[19]As their numbers grew, quantitative scholars successfully campaigned for the establishment of data archives, special repositories designed to preserve and provide access to machine-readable collections of survey, census, polling, and legislative data. See Kathleen M. Heim, "Social Scientific Needs for Numeric Data: The Evolution of the International Data Archive Infrastructure," *Collection Management* 9 (Spring 1987): 1–53.

[20]Morton and Price, *ACLS Survey of Scholars*, 33. The ACLS study represents the only currently available direct survey of scholars on their use of computers. But the survey polled only scholars who are members of professional associations. For the past few years, EDUCOM and the University of Southern California have conducted an annual survey of academic computing directors on campus planning, policies, and procedures affecting the use of desktop computers. According to reports by academic computing centers, 39.5% of faculty at two year public and four year public and private colleges and universities have access to or own computers. This figure, however, is considered unreliable, as it is based on estimates by academic computing staff, rather than on direct counts. Furthermore, no one believes that actual usage has dropped from 1985 to 1991, as implied by the discrepancy between the ACLS and EDUCOM/USC figures. According to Kenneth C. Green, the EDUCOM/USC survey developer and author of the report on the findings, "our limited knowledge about student and faculty access to and use of technology is appalling." Green argues that a direct survey of scholars is needed to identify actual computer usage. See USC Center for Scholarly Technology *Newsletter*, "Despite Budget Cuts, Campuses Attempt to Maintain Computing Services," (October 1991); Kenneth C. Green, "A Technology Agenda for the 1990s," *Change* 23 (January/February 1991): 6–7; and Kenneth C. Green and Skip Eastman, *Campus Computing 1990* (Los Angeles: University of Southern California, Center for Scholarly Technology, 1990).

providing individualized assistance to students.[21]

The driving force behind the advance of information technology has been the development of faster, smaller, and cheaper electronic devices, which can be used to produce machines with greater capabilities for manipulating and processing information. These machines have in turn inspired the production of more powerful and imaginative programs and solution techniques (computational methods or algorithms) for solving problems that would be intractable without this new computational power. The availability of increased computational power, in turn, has enabled the design of new computer hardware and software, producing a snowball effect in which each new generation of system facilitates the design of its successor. This process can be expected to continue until designers reach the fundamental limitations of physics and exhaust all technological alternatives, which does not appear imminent. An improvement in computational power of six orders of magnitude (a factor of a million) over the past two decades can be attributed to roughly equal improvements (three orders of magnitude each) in hardware and software.[22] It is not unreasonable to expect a comparable improvement to occur over the next two or three decades. As a result, in the next few decades an unimaginable amount of computational power will be available to scholars. This capacity compels the archival profession to determine the implications of the use of information technology by scholars for conventional archival practices.

Although the future evolution of information technology is fairly predictable in broad outline, predicting precise details of how the technology will evolve is more difficult. For our purposes, however, it is the broad outline of these trends that is most important. Our discussion of technology, therefore, avoids mentioning specific devices, techniques, or research results. Instead, the next section examines trends of information technology that are likely to have the greatest impact on scholarly communication—and, by implication, on archives management. The focus here is on broad descriptions and projections most relevant to the future of scholarly research. Later in this paper we examine how scholars are actually using information technology in their current work.

OVERVIEW OF INFORMATION TECHNOLOGY TRENDS

The two most obvious—and for the purpose of this paper, the most important—information technology trends that pertain to scholarly communication are *end-user computing* and *connectivity*. These trends are distinct and separable, and each is discussed in detail below. Ultimately, however, it is the integration of the two that will have the greatest impact on scholarly communication. End-user computing enhances the autonomy of the researcher, i.e., the researcher's ability to use the power of computation to conceptualize and execute research without sacrificing intellectual control by delegating computational tasks to specialists. Connectivity enhances the researcher's abilities to access data, collaborate, seek input and feedback, and disseminate ideas and results. The confluence of these trends produces a rich interplay of synergistic effects, which are explored below.

A number of more specific technology

[21]See Miall, *Humanities and the Computer*, 4; and Jean-Claude Gardin, "The Future Influence of Computers on the Interplay Between Research and Teaching in the Humanities," *Humanities Communication Newsletter* 9 (1987): 17–18.

[22]*Grand Challenges: High Performance Computing and Communications, The FY 1992 U.S. Research and Development Program, A Report by the Committee on Physical, Mathematical, and Engineering Sciences, Federal Coordinating Council for Science, Engineering and Technology, Office of Science and Technology Policy* (1991), 14–15.