specific technology, including artificial intelligence, end-user publication and distribution, hypermedia, and visualization and virtual reality, are likely to have a significant impact on the research process. The effects of these trends, along with changes in scholarly practice that are already under way, point to a future in which researchers use computation and electronic communication to help formulate ideas, access sources, perform research, collaborate with colleagues in their own and other disciplines, seek peer review, publish and disseminate results, and engage in many professional and educational activities. Far from being visionary, this future is already present: It is currently being experienced by significant and increasing numbers of researchers from many disciplines.

How should the archival profession respond to these changes in scholarly practice? Are the techniques and functions developed by the archival profession to manage printed media adequate for the needs of researchers who operate in a global electronic networking environment? Should established archives convert printed material to machine-readable form? If so, what selection criteria should be used? What constitutes the "reference function" in the age of research and education networks and electronic communication? These issues first are addressed through case examples drawn from the experience of the library community, and then by a set of recommendations specifically designed for the archival profession.

RESPONSES BY THE LIBRARY PROFESSION TO CHANGING RESEARCH PRACTICES

On several occasions in the recent past, libraries and professional associations have sponsored inquiries into scholarly use of technology. For example, the American Council of Learned Societies conducted a survey in 1985 to 1986 that noted the rapid increase in the use of technology by the scholarly community.[147] In a more recent study sponsored by the Harvard College Library and the American Council of Learned Societies, the Conference on Research Trends and Library Resources brought social science and humanities scholars together to explore new trends in research methods. Scholars spent several days considering the impact of new technology, interdisciplinary research, and the use of innovative formats of materials on their work.[148] In another effort, the American Academy for Arts and Sciences sponsored an exchange between scholars and librarians to develop policy recommendations to improve access to library materials. A key observation shared by these inquiries is that scholars increasingly want online access to electronic source materials available through personal computers in their homes or offices.

Visionary leaders within the library community are beginning to implement pilot projects designed to improve the library's role in advancing scholarship and its response to changing research methods. These projects hold particular interest for archivists as the key distinction between the printed form of archival and library materials is disappearing. Indeed, in an electronic environment, concepts, such as "unique" and "multiple," which have been used to distinguish archival sources from library materials, are less meaningful. It is not surprising that librarians hold differing opinions regarding the most appropriate role for libraries in the electronic environment. Some librarians argue for continuity—the continued commitment to collection devel-

[147]Morton and Price, *The ACLS Survey of Scholars: Final Report of Views on Publications, Computers, and Libraries,* 33.

[148]Lawrence Dowler, "Conference on Research Trends and Library Resources," 22–23, February 1990, unpublished draft report (Cambridge, Mass.: Harvard University, Widener Library, n.d.)

opment. Those who hold this position argue for consolidating library resources in the activities of selection and collection management and for relinquishing a role for libraries in converting source materials to electronic form. In contrast, the proponents of change claim that the continuity approach could mark the end of the era of free access to information because commercial vendors would step in to convert library materials and make them available for a fee in electronic form. The advocates of information-based institutions champion a new vision of the library without walls—an enterprise comprising many electronic libraries (including commercially produced products) that provide network access to patrons. Regardless of their perspective, both sides agree that patron demands for electronic access to library materials will be met by someone.[149] This section examines several leading projects and programs undertaken by the library community to address changes in the research environment, focusing on four new trends in professional activity: (1) promoting high-performance connectivity, (2) conversion of printed materials to machine-readable form, (3) software engineering for next-generation systems, and (4) transformations in professional roles.

Promoting Connectivity

In the last few years, library leaders have forged a new political alliance with academic computing centers and the telecommunications industry to support the development of high-performance computing networks capable of rapidly transmitting huge amounts of data and high-resolution graphics. A high-performance computing network is needed because the several thousand academic, governmental, regional, and private networks that already operate worldwide cannot transmit data and images fast enough or in large enough chunks to keep pace with the needs of scientific research. Furthermore, faster networks with higher bandwidths will expand infrastructure support for scholarly exchange of visually-oriented material (such as that required for medical research), online electronic publishing, and high-speed interchanges of text and graphics in the arts and social sciences.

Recognizing the need for infrastructures (or "highways") to disseminate materials electronically, the Association of Research Libraries (ARL) in 1990 joined with academic and administrative computing centers to form the Coalition for Networked Information (CNI). CNI is a collaboration among three distinct groups—EDUCOM, CAUSE, and the ARL—who have united to "promote the creation of and access to information resources in networked environments in order to enrich scholarship and enhance intellectual productivity."[150] The most immediate focus of the coalition's work is to establish the National Research and Education Network (NREN), a federally supported high-performance computing network. In the interim, NSFNet (a network administered by the National Science Foundation), in conjunction with the thousands of other existing networks, serves as the precursor for the future operational NREN.

The coalition is optimistic about implementing NREN as a gigabit-per-second network. In 1991, Congress passed the High Performance Computing Program that establishes the mandate for NREN. Although the original motivation for NREN emerged from the scientific community's requirements, the broader constituency rep-

[149]For two perspectives on the topic see: Stephen E. Ostrow and Robert Zich, in *Research Collections in the Information Age: The Library of Congress Looks to the Future,* edited by John Y. Cole (Washington, D.C.: Library of Congress, 1990).

[150]From Coalition for Networked Information, *Mission Statement,* March 1990.

resented by CNI envisions a network devoted to kindergarten through high school (K–12) programming, as well as leading-edge research. Indeed, EDUCOM recently designated a full-time staff position for the development of network K–12 programs. CNI's commitment is to the development of a network available to all the nation's teachers, students, and researchers.[151]

When fully implemented, NREN will allow researchers at universities, national laboratories, nonprofit institutions, government research centers, and private industry to exchange sources, communicate in real time, share preliminary findings, and disseminate publications electronically. Indeed, the dramatic changes in the ways research is conducted and information is exchanged are key factors driving the development of NREN. Through remote access hookups, NREN will provide the nation's researchers and students, regardless of the type and size of their college, with the same computing tools, data files, supercomputers, electronic libraries, specialized research facilities, and educational technology.[152] It is anticipated that NREN will support the transmittal of at least 1 billion bits of data every second by 1995.

Recognizing the impact a network with such unprecedented speed and capacity will have on their institutions, librarians have joined with other information professionals to support the development of NREN. As coalition members, librarians are participating in a range of NREN-related activities, including CNI's seven working groups on: (1) encouragement of academic publishing; (2) expansion of commercial electronic publishing; (3) development of network architectures and standards; (4) formation of proposals for legislative codes, policies, and practices; (5) organization of directories and resource information services; (6) creation of teaching and learning programs; and (7) improvement of network management and user education.

Through the activity of building a high-performance network, a new vision of the library is emerging. No longer simply a place to visit, libraries are becoming "virtual enterprises" of electronic information.[153]

Conversion

As a concrete step toward the realization of networked electronic libraries, some repositories have begun to convert to machine-readable form records originally created on paper. The American Memory Project at the Library of Congress (LC) represents a leading example of this type of effort.[154] Over the next five years, the Library of Congress, with nearly $1 million per year in congressionally appropriated funds along with private donations, will convert into electronic form large archival collections from their holdings relating to

[151]From Kenneth King, president, EDUCOM, unpublished paper presented at the "NREN Governance and Policy" session at National Net'91 Conference, 22 March 1991, Washington, D.C.

[152]See *NREN: The National Research and Education Network* (Washington, D.C.: Coalition for the National Research and Education Network, 1989).

[153]For additional information on NREN see most recent issues of *EDUCOM Review*; also, Jean Loup, *National Research and Education Network: Overview and Summary* (Washington, D.C.: Association of Research Libraries, July 1990); Charles E. Catlett, "The NSFNet: Beginnings of a National Research Internet," *Academic Computing* 3 (January 1989): 18–21, 59–64; Stephen B. Gould, "Computing and Telecommunications in the Federal Government," *CRS Review* 11 (July/August 1990): 12–15; for information on CNI, see organizational papers available from Paul Peters, CNI, 1527 New Hampshire Avenue, N.W., Washington, D.C. 20036.

[154]Additional programs now under way include the Hunt Library at Carnegie Mellon University and the Image Transmission Program at the National Agricultural Library. Other libraries are creating CD-ROMs on specialized subject areas. The Marine Corps has announced that it is compiling an online version of the Marine Corps University warfighting collection that will allow marines to "fight smart" wherever they are stationed; see Kevin M. Baerson, "Marines Put Library On-Line," *Federal Computer Week*, 5 (2 September 1991): 1, 4.

American culture and history.[155] The purpose of the project is to use advanced technology to make electronic versions of collections available to libraries across the country.

The collections chosen for the initial round of conversion primarily document aspects of turn-of-the-century life in America. They are drawn from a cross-section of original formats, including rare pamphlets, early motion pictures, sound recordings, personal papers, and still photographs. A variety of image, text, and audio types will be linked to catalog information in the standard MARC (MAchine-Readable Cataloging) format.

In fiscal year 1991, the Library of Congress prepared four collections for electronic dissemination, including about 300 broadsides from the Continental Congress and Constitutional Convention; three hours of sound recordings of speeches (sixty examples) of political leaders during World War I and the presidential election of 1920; two dozen short motion pictures of President McKinley at the start of his second term and at the 1901 Pan-American Exhibition in Buffalo, New York; and about 25,000 photographs from a well-known postcard and scenic-view company founded by William Henry Jackson. By the end of 1992, the library will supplement these with collections of Civil War photographs, approximately 350 African-American pamphlets (11,000 printed pages written between 1820 and 1910), local history books from California, early films of New York City, and life histories from the Federal Writers' Project.

The library's selection process attempts to strike a balance between popular, readily available collections and unprocessed collections that comprise a backlog arrearage. Selecting an arrearage collection provides an impetus for processing it. As selections are made, the planners consult both with Library of Congress curators and with outside scholars. The first set of American Memory collections is being evaluated in forty school, university, public, and special libraries to assess patterns of use. The results of this evaluation will provide further guidance.

Compared with all the holdings of the Library of Congress, American Memory will convert only a relatively small amount during the first few years. The program's extent reflects the high cost of conversion, the institution's desire to reduce its arrearage, and the typical difficulties encountered in the introduction of a new technology. To maximize the use of what it has prepared, however, the library is placing special emphasis on educational applications. Besides providing the collections proper, American Memory's presentation also will include introductory information in interactive, computerized form and in print.

The ultimate goal of the American Memory project is to make materials available via telecommunications, but this goal will be fully realized only in the later 1990s. Until then, the collections will be disseminated on disks: CD-ROMs for digital information and analog videodiscs for motion picture and some still photographic collections. But whether on disk or in a network, every American Memory working prototype will model what Ricky Erway, an American Memory associate coordinator, describes as a "library without walls." American Memory will be operating as a pilot project through 1995.[156]

[155]The American Memory project has received gifts from the David and Lucille Packard Foundation, the Annenberg Fund, Inc., Armand Hammer's Occidental Petroleum Corporation, and Jones International, Ltd., as well as gifts or loans of equipment from Apple Computer, IBM, and Pioneer. See Library of Congress, "American Memory," LC *Information Bulletin* (26 February 1990): 83–87.

[156]For further information on American Memory, contact the Library of Congress, Special Projects Of-

Software Engineering

Many libraries are considering ways to expand bibliographic access as part of their plans to develop next-generation library systems.[157] But few are taking as ambitious or comprehensive an approach to the process as the staff at Carnegie Mellon's University Libraries. With a $1.2 million grant from the Pew Memorial Trust and several million dollars of donated hardware from Digital Equipment Corporation, the library is developing a system that will provide the university's faculty, students, and administrators with access to bibliographic databases, full-text documents, and network gateways.[158] Library Information System II (LIS II), implemented in 1991, is designed to improve the quality of retrieval and delivery of textual information to users. In a bold departure from the standard approach to library automation, Carnegie Mellon separated its public catalog from other library administrative functions. As such, LIS II is devoted strictly to user-oriented retrieval, whereas OCLC's LS/2000, an automated system with integrated modules, is in use for other aspects of library administration.

The technical goal of LIS II is to produce for networked campuses an affordable library retrieval system that adheres to available standards. During the first phase, the system will run on University Library installed workstations. Since January 1992, LIS II has been available across campus through workstation or VT 100 access. A Macintosh interface is scheduled to be released by the end of 1992. The application goals of the current system are to provide the following:

- Online bibliographic access to all university resources
- Bibliographic access at the article level to journal literature
- Electronic access to external databases
- Online access to a range of campus information
- Online access to textual information[159]

The system's distributed architecture has been designed to support further research and development toward the realization of an electronic library.

Although the system's software supports standard bibliographic retrieval, it also provides enhanced access to select anthologies, plays, edited collections, exhibition catalogs, and conference proceedings. Several thousand bibliographic records for these

fice, Washington, D.C. 20540, (202) 707-6233. Information on the project from discussions by Avra Michelson with Ricky Erway on 28 December 1990 and Erway and Carl Fleischhauer on 4 February 1991 and from documents supplied by the Library of Congress.

[157]For the development of enhanced bibliographic records, see, for instance, Van Orden, "Content-Enriched Access to Electronic Information," 27–32; Flo Wilson, "Article-Level Access in the Online Catalog at Vanderbilt University," *Information Technology and Libraries* 8 (June 1989): 121–31; and Katharina Klemperer, "New Dimensions for the Online Catalog: The Dartmouth College Library Experience," *Information Technology and Libraries* 8 (June 1989): 138–45; the Klemperer article also discusses Dartmouth's approach to the development of an integrated campuswide information system.

[158]Information for this section is from a site visit by Avra Michelson to the University Libraries that included meetings with Thomas Michalak, Tom Dopirak, and Denise Troll on 27 March 1991. See also two reports on the work of the project: Denise A. Troll, *Library Information System II: Progress Report and Technical Plan,* Mercury Technical Report Series, no. 3 (Pittsburgh, Pa.: Carnegie Mellon University, 1990); and Nancy H. Evans et. al., *The Vision of the Electronic Library,* Mercury Technical Report Series, no. 1 (Pittsburgh, Pa.: Carnegie Mellon University, 1989). Also see William Y. Arms and Thomas J. Michalak, "Carnegie Mellon University," in *Campus Strategies for Libraries and Electronic Information,* edited by Caroline Arms (Bedford, Mass.: Digital Equipment Corporation, 1990), 243–73.

[159]The University of California at Berkeley's Office of Information Systems and Technology also is developing a campus networked information system to support bibliographic and nonbibliographic databases, full-text documents, nontextual documents, and hypermedia links.

types of publications have been embellished manually or by establishing system links with nearly one dozen commercial products that include tables of contents, title pages, and book reviews. One-page abstracts are included in the bibliographic records of campus-issued scientific and technical reports. The intent of this type of record enhancement is to improve the relevance of system retrievals.

Besides record enhancement, the staff plans to mount two types of full-text databases, journal articles and campuswide information, on the system. Elsevier, Pergamon, and the Association of Computing Machinery (ACM) have agreed to provide the University Libraries with machine-readable journals and technical reports in the subject field of computer science. ACM will provide extensive runs of four of its publications: *Computing Reviews* (ten years), *Collected Algorithms* (twenty-five years), *Communications* (two years), and *Guide to Computing Literature* (ten years). Carnegie Mellon is also negotiating an agreement to make the publications of the American Association for Artificial Intelligence available in machine-readable form, and it is working with academic research institutions to collect machine-readable computer science technical reports. Concentrating the full-text offerings in an area such as artificial intelligence and computer science will allow the University Libraries to further evaluate scholarly information needs by studying the use of textual information in a single discipline.

The University Libraries also are installing a CD-ROM jukebox system from University Microfilms, Inc. That system includes full-text images of general and business journals linked to bibliographic citations in tape-mounted databases on LIS II. In the final phase of the project, the images will be delivered to workstations across campus.

The full-text, campus-oriented documents require an indexing scheme entirely different from that developed for standard bibliographic data. The new system will provide campus software licensing and availability information, career and placement resources, the Carnegie Mellon Policies and Procedures Manual, the undergraduate catalog, user help files for other campuswide systems, listings of faculty and staff publications (including research profiles), and indexes and full text of campus newspapers. Standard office reference materials, such as phone books, encyclopedias, and dictionaries, are already available.

Development of the system's user interface is based on staff findings on user work habits and information-seeking behaviors. According to the research, patrons rarely refer to documents in isolation from other activity. For this reason, the LIS II architecture has been designed to integrate with a larger work environment, supporting linkages to word processors, databases, e-mail, and parallel applications. Toolkits (special software routines) permit LIS II users to make individual databases available across the network. Other features allow patrons to store searches for reuse, move in one keystroke from a journal article citation to the full text of the article, and improve queries by browsing indexes that reveal how often terms are used. The windowed screen environment can be customized by each user.

The creation of an electronic library linked to other electronic libraries requires sustained effort. LIS II provides in substantial measure an architecture to support full-text electronic delivery of documents in libraries. In creating this system, the developers clarified many issues and resolved other important issues in the areas of distributed storage and retrieval systems, information capture and representation, information retrieval and delivery, and management and economic concerns. Carnegie Mellon plans

to make the software developed for LIS II available to other libraries.

Transformations in Professional Roles

Library literature contains many proposals for new roles for library professionals in the electronic age.[160] Among these the programmatic achievements of the Laboratory for Applied Research in Academic Information serves as one of the best operational models for redefining the librarian's role on campus. A division of the William H. Welch Medical Library at The Johns Hopkins University, the laboratory is a collaboration among academic scholars, scientists, and librarians. They share responsibility for the creation, structuring, representation, dissemination, and use of scholarly knowledge through the use of computing and communication technology. Created in 1987 by Nina W. Matheson and Richard E. Lucier, the Laboratory explores strategies for integrating the library more fully into the scholarly communication process.[161] Lucier has developed what he terms the "knowledge management model," which extends the library's traditional storage and retrieval and information transfer functions to include a third function, knowledge management.

In the knowledge management model, librarians are teamed with content specialists, software engineers, and social scientists to identify the specialized information needs of a constituency and then address the needs with the aid of information technology. In this model, the laboratory performs three types of work: (1) knowledge base and software development; (2) research and scientific support through ongoing needs assessments and quality control of data, education and training; and (3) service through the management of the computing and communications infrastructure. The social scientists assess information needs by using standard methodologies, such as participant observation, formal and unstructured interviews, and document analysis.

The laboratory recently received a three-year grant from the Council on Library Resources (CLR) to document the knowledge management model and explore the feasibility of implementing the model in nonmedical environments. The CLR funds also support an invitational symposium on knowledge management. The laboratory's key projects have been the development of the Online Mendelian Inheritance in Man (OMIM) and the Genome Data Base, which are comprehensive scientific sources used by geneticists worldwide for gene mapping, genetic disease diagnosis, and patient care. These online projects allow an international group of scientists to collect, organize, and electronically distribute mapping and disease information on approximately 100,000 genes that regulate human health and development. The constantly evolving Genome Data Base is maintained by more than one hundred scientists around the world. Lucier considers the database to be a form of dynamic, interactive publication that, unlike static print publications, always provides the most current information and analysis by the most respected scientific authorities.

[160]See, for instance, the ideas developed by Eldred Smith in his book *The Librarian, the Scholar, and the Future of the Research Library* (New York: Greenwood Press, 1990), especially 60–63 and 83–84. Articles by Bert B. Boyce and Kathleen M. Heim, "The Education of Library Systems Analysts for the Nineties," and John Corbin, "The Education of Librarians in an Age of Information Technology," in *Computing, Electronic Publishing and Information Technology: Their Impact on Academic Libraries,* edited by Robin Downes (New York: Haworth Press, 1988), 60–63 and 83–84, respectively; and Timothy C. Weiskel, "University Libraries, Integrated Scholarly Information Systems (ISIS), and the Changing Character of Academic Research," *Library Hi Tech* 6 (1988): 7–27.

[161]This section is based on briefings of Avra Michelson by Richard Lucier and Valerie Florence, 7 May 1991; see also Richard Lucier, "Knowledge Management: Refining Roles in Scientific Communication," *EDUCOM Review* 25 (Fall 1990): 21–27. For information on particular projects, see *Welch Library Issues,* vol. 2, nos. 1, 4, and 6.

Through the development of the Genome Data Base, OMIM, and other projects, the laboratory has demonstrated that knowledge management represents a "practical working alternative to existing roles and relationships in the creation and management of scholarly knowledge."[162] Lucier will expand his work in the development of the new Center for Knowledge Management at the University of California at San Francisco.

This section reviewed some of the library community's strategies. The next section recommends actions that the archival profession can take to respond to changing research methods. These actions are an important step toward confronting the transformation of scholarly practice that is as imminent as the new millennium.

CONCLUSION AND RECOMMENDATIONS

The scholarly use of information technology is resulting in dramatic changes in research practices. Essentially two trends are evident: one toward end-user computing and the other toward connectivity. To an increasing extent, social scientists and humanists are performing their own computation in the context of ever greater connectivity. The scholarly use of computers and communication technology for research and information exchange has both short-term and long-term ramifications for archival practice. In the short term, the archival profession needs to address the increasing prominence of network-mediated scholarship. In the long term, the role of the archival profession in the development of next-generation archives that operate in conjunction with global networks needs to be defined. The following recommendations suggest concrete actions the archival profession can take to address both of these issues during the next decade:

- Establish a presence on the Internet/NREN.
- Make source materials available for research use over the Internet.
- Create documentation strategies to document network-mediated scholarship and the development of research and education networks as a new communications medium.
- Develop archival methods suitable for operation with NREN.
- Take user practices and computational capacity into account in establishing policies on the management of software-dependent records.
- Recognize and reward initiatives that advance (a) the archival management of electronic records; (b) the response to scholarly use of information technology; and (c) a network-mediated archival practice.

These recommendations are considered in the three-part discussion below.

Part I: Establishing a Network-Mediated Archival Practice

The archival profession, first and foremost, must respond to the emergence of network-mediated scholarship. New methods of searching for sources, communicating with colleagues, disseminating research findings, and providing instruction suggest that scholarly communication is increasingly mediated through electronic networks. The existing Internet and the future NREN represent the new meeting ground where scholars turn for bibliographic information, scholarly dialogues and feedback, the most current publications in their fields, and high-level educational offerings. Increasingly, full-text versions of journals, magazines, newsletters, and even

[162] "Knowledge Management: A Collaboration of Academic Scholars, Scientists and Librarians," unpublished statement on the three-year project sponsored by the Council on Library Resources, The William H. Welch Medical Library, Laboratory for Applied Research in Academic Information (15 July 1990).