History Review: The Development of Information Science in the United States

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Introduction

This paper expands on the summary provided at the conclusion of the conference on the history of science information and information science. It provides a brief review of the history of developments in those fields in the United States, including consideration of some contextual dimensions within which those developments should be seen. I am going to discuss seven timelines spanning the past fifty years, divided into three time periods: 1948–64, 1964–80, and 1980–98. I conclude with predictions about the coming five-year period. The seven timelines are the context of scientific, social, economic, and political developments; the context of commercial, industrial, and consumer information resources; development of the underlying technologies; the context of publishing; the context of library concerns; development of library automation; and development of information science and services. These timelines all interact with each other, and I will first try to highlight some of their interactions. Of special importance were developments in the commercial, industrial, and consumer sectors of parallels to those in the library and information science sectors. In many respects, though almost unheralded, the development of automation in libraries demonstrated the feasibility of its application in the larger arena. I think especially of the leadership of the National Library of Medicine in proving the feasibility of high-quality typographic output from computers, thus laying the groundwork for computer-controlled photocomposition in publishing. I think of the development of online reference data services, first demonstrated in libraries and then finding great acceptance in industry. I think of the distribution of CD-ROMs, which found their first real market in libraries. As I proceed through this history, these interactions should be evident.

Also of special importance has been the effect of technological capabilities not only on what could be done but also on the very perception of how to do it. This was evident in the early years, when the limits of punched-card technology as well as the means for the logical processing it embodied largely determined how people thought about using technology. Since then the capabilities of the technology have grown so dramatically that an understanding of how to use it in information science continually lags behind.

But perhaps the most important of the interactions were the effects of the scientific, social, economic, and political context. They provided and continue to provide the rationale for commitment of resources to all of the developments presented here.

I will interlace into the discussion some elements related to my own professional involvement because it represents the perspective I bring to the developments and to some extent my own participation in them. In this way you can judge what I say in the light of my experiences.

1948 to 1964

I came to this field during the period from 1948 to 1964. At the beginning of it, after receiving my Ph.D. in mathematics from UCLA, I started in systems work and the use of computers. In the middle of the period I gained some knowledge of applications to information retrieval. During the last third I formed my own company and by the end of the period had joined the UCLA School of Library Service.

From the period when Vannevar Bush was the science adviser to the president, the needs for information in science and technology provided a continuing rationale for development of automated information management systems. Indeed, this period started with Bush's frequently cited article, "As We May Think" (Bush, 1945a). In a very real sense it foretold virtually everything we have since seen in terms of development in our field. Much though that article has been cited, however, a far more important document is the earlier 1945 report of the Office of Scientific Research and Development (OSRD) of which Bush was chair. It urged continued support for scientific research after World War II ended. By doing so, it led to one of the most important steps in the history of science in the United States: It proposed what in 1950 became the National Science Foundation and the National Institutes of Health (Bush, 1945b).

Of specific relevance to science information and information science, the OSRD report identified many of the continuing themes that have been important to our field: international exchange of scientific information, publication of scientific information, lifting of security restrictions for a broad dissemination of scientific information, encouragement of publication, and library aids. In the discussion of library aids it states, "Adequate technical libraries are an indispensable tool for research workers." Then it makes specific reference to information technology: "It seems probable that use of cataloging and sorting devices now available in the form of business machines and microfilm technique might go far to improve present methods of searching the literature and making bibliographies" (Bush, 1945b, pp. 112–115). Indeed, by the end of the period from 1948 to 1964, the realization of that conjecture was well under way. Let us examine each of the seven timelines during that period.

The Scientific, Social, Economic, and Political Contexts

During this period the United States was the dominant economic power in the world and the major producer of scientific research publications. The reason is evident: It was the only major country that had not suffered catastrophic losses during World War II. Its economic infrastructure was intact, as was its academic superstructure. Fortunately, I think, it used its economic power wisely, as best represented by the Marshall Plan that made U.S. resources available for the rebuilding of Europe and the Far East. From the standpoint of science information, at the beginning of this period (1948–50), the United States produced more than 50 percent of the world's scientific publications.

This was the period of the Cold War, which reached its peak during the Korean War and the Cuban missile crisis. One of the most critical events came in the middle of this period—the launching of *Sputnik* by the Soviets in 1957. This event shocked the military, industrial, and scientific establishment of the United States and led directly to some of the most crucial developments in our own field.

Even before those epoch-making events, though, there was a continuing emphasis on the need for information services to support U.S. national defense. In the early days the needs lay in the management of the flood of documents taken from Germany after World War II; this "documentation" clearly required development of new tools to support that management and the related tasks in storing and retrieving data from such massive amounts of material. Later, though, as the Cold War became more intense, the intelligence community—the Central Intelligence Agency (CIA), National Security Agency (NSA), and the intelligence arms of each of the branches of the Armed Services—required means for assembling, storing and retrieving, and analyzing even more massive amounts of data. Their needs more than any others supported the development of computer hardware and software and led to the development of "systems work" as the means for assessing requirements and implementing efficient systems (*Documentation, indexing, and retrieval*, 1961).[1] The operational arms of branches of the Department of Defense, especially the Air Force, also required the development and implementation of systems that would support their operating requirements. The "early-warning" systems of the North American Aerospace Command (NORAD) and the Strategic Air Command (SAC) and the tactical systems to support troops in the field both led to significant investments in information technologies by each of the branches. They also led to commitments of the major aerospace companies to work in the field of information technology. Indeed, the Air Force and the Office of Na-

[1] In *Documentation, indexing, and retrieval*, see especially pp. 63–64 (CIA Intellofax system) and p. 65 (Minicard system).

val Research were among the most important sources of funding for research in information science.

That was the context for the recommendations concerning science information in the Report to the President and for Bush's "As We May Think." But the demands reached a crescendo as a result of *Sputnik*. The science adviser to the president became even more an advocate for science information. The National Science Foundation launched its Office of Science Information Service to support development and implementation of automated systems and to sponsor the necessary research; of special importance was its funding of the automation of Chemical Abstracts Services. It also published several summaries of both research activities and operational services ("Current research and development," 1957–1969; "Nonconventional scientific and technical information," 1958–1966; "Specialized science information services," 1961).

I have always regarded one development in the U.S. military during this period as an important application of information science, but one which the field has largely ignored. It was the Federal Parts Cataloging program, which started at the very beginning of this period and became the basis for inventory management throughout the federal government and, indeed, in NATO activities as well as in the U.S. military (Hayes, 1992).

Further, consistent with the recommendations of the OSRD, health care and related research became a priority of the federal government. The National Institutes of Health were established and the Surgeon General's Library became the National Library of Medicine. Toward the end of this period the National Library of Medicine launched its efforts to automate the production of *Index Medicus* (Miles, 1982).[2]

Commercial, Industrial, and Consumer Contexts

In this period there was limited recognition of the role of information in our society. Its use within companies was primarily for the purpose of internal accounting, and the amount of data involved was small. The number of transactions handled, while large in terms of the processing capabilities of the time, was tiny compared with the situation today. There was at best limited use, if any, of external information, although industrial special libraries did serve as a means for access to it.

I had a discussion in 1960 with the processing staff of Bache & Company (then one of the major stock brokerage firms on Wall Street). I was a consultant to them because they were implementing one of the first computer systems in such a context. They proudly announced that they had designed the system to handle three times the workload expected during a then-typical day on Wall Street, in which the volume of activity was three million shares a day. I asked what they would do when the volume of activity increased to ten million shares per day, and they looked at me as though I were crazy. That level, however, was reached within seven years and today is consistently over five hundred million shares per day.

For the consumer, information was a little-recognized commodity. At the beginning of the period movies were the dominant means of entertainment, though television was just beginning to pervade our lives. (I vividly recall watching, through store windows, the telecasts of the McCarthy hearings and especially the devastating assessments of Edward R. Murrow and of Judge Welch.) Further, sales of books, newspapers, and magazines in the United States were at about $1.4 billion a year—$7.67 per capita.

Information Technology

It is with almost shock that I recall the nature of the technology during that seventeen-year period and compare it with what we have today. In the beginning data processing meant punched cards and key-operated accounting machines, with punched tape (like Teletype tape) as the "common language" for communication among machines. Computers were limited in capabilities, in numbers, and in applications. I worked at UCLA on one of the first of them, the Bureau of Standards Western Automatic Calculator (SWAC). While large and fast for the time, its capabilities were exceptionally limited. Today I can hold in my hand greater computing power, greater functionality, and greater ability to apply it and use it—and it all runs on two AA batteries!

The first small-scale computers for application in business and similar operations (among which I would include libraries and information services) appeared in the early 1950s, and larger systems—mainframe computers—became widespread by the end of the period. But all of that equipment suffered from the lack of adequate means for input, storage, display, and output of data. Punched cards and punched tape were the only means for input, and they operated at data rates roughly equivalent to ten characters per second—the speed of

[2] In Miles, see especially p. 365 (support grant from Council on Library Resources in 1958), pp. 372–373 (GRACE graphic arts composing equipment in 1963), and p. 378 (Medical Library Assistance Act of 1965).

Teletype. Vacuum tubes (cathode ray tubes, or CRTs, as they were called) and then, later, magnetic cores were the means for storage of operating programs and data during processing; but both were exceptionally expensive and limited in capacity (6,000 bytes would be a big internal memory). For large-scale data storage we had magnetic tapes and magnetic drums—each slow and with inherent limitations in the ways they could be used. For display we had the most primitive of CRT units, with low resolution and presenting only limited amounts of data. The means for output were punched-card tabulators, with upper-case-only fonts and which operated again at the equivalent of ten characters per second. Thus, even though the computers were fast, they could not do much, given the limited internal memory. They were inherently limited by capabilities for storage of large files and the slow speed of input and output.

The Publishing Context

During this period publishing was much as it had always been. Composition was essentially manual; although there were a few isolated experiments with computer technology, they were completely outside the mainstream of commercial publishing.

The form of publication was simply print, using the traditional means for achieving it. Xerographic means for duplication were just beginning to have an impact toward the end of the period. Indeed, in the late 1950s, when Walter Carlson was attempting to get companies interested in his invention, the response was almost universally "What's the market for replacing carbon copies?" Only the Haloid Corporation (which later became Xerox) in the mid-1950s was willing to take the leap into what became an overwhelming phenomenon.

The computer as a means for publishing simply had not yet arrived.

The Library Context

Where were libraries during this period? There was increasing recognition of the importance of libraries, both as part of the activities to which I have referred and independent of them. The Library of Congress had for many years been the primary center for production and distribution of catalog cards, through its Card Production Service. But that was primarily of significance to the libraries of the country, not to the using public.

What was significant to the public was the fact that Congress passed the Library Services Act (later expanded into the Library Services and Construction Act), which, among other things, fostered the creation of library networks that were of vital importance as automated systems became important to libraries (Holley, 1983). The Medical Library Act of 1956 made the Surgeon General's Library (first created in 1840) into the National Library of Medicine (Miles, 1982, pp. 353–355). In 1862 Congress had created the library of the Department of Agriculture, and in 1962 it too became a national library.[3] All of these acts were clear recognition of the importance of libraries.

Internal Technical Processing

The next thread in the set of timelines is the development of automation for internal technical processing in libraries. Until virtually the end of the period progress in this respect was essentially nil. Of course, there were the highly successful uses of microfilm in the management of circulation records, especially in the public libraries, and there were many abortive efforts to use punched-card equipment for that purpose. There were similarly abortive efforts to deal with serial records, again using punched-card equipment. But for the core technical service functions—acquisition and cataloging—there were not even any abortive efforts. The problems were too great, especially with respect to the number of catalog entries involved and the overwhelming costs in converting them to machine-processible form.

Among the abortive experiments, two were of historical interest. The first was the effort in 1930 by Ralph Parker at the University of Texas. Parker wanted to try using a punched-card system for circulation control. The library director, Don Coney (who later became Director of Libraries at the University of California, Berkeley) said, "OK. Here's $300, but use it wisely" (Hayes & Becker, 1970). The second was the effort, again by Ralph Parker, now at the University of Missouri, to initiate an evolutionary approach to an integrated library records system (Parker, 1952).

By the end of the period the Council on Library Resources had begun to play crucial roles in the successive stages in development of library automation. The council was especially important in providing support to the National Library of Medicine in its effort to auto-

[3] The Organic Act of 1862, which established the Department of Agriculture, clearly identified the need for a library within it, and the first librarian was appointed in 1867. Over the years, the Department of Agriculture Library became, de facto, a national library but it was not officially designated as the National Agricultural Library until 1962, when Memorandum No. 1496 of the Secretary of Agriculture did so.

mate the production of *Index Medicus* (Miles, 1982) and to the Library of Congress in its first explorations of the use of computer-based systems (King, 1963). More generally they were concerned with alternative means for producing catalogs and making catalog data available.

In that respect one of the important attempts to apply computers to provide access to catalog data was the production of book-form catalogs, especially for union catalogs, which contain records of a set of libraries. This approach has a history of some importance to the development of librarianship in the efforts of Charles Jewett to use stereotypes for the production of a national union catalog ("Fifth annual report," 1851, pp. 28–41, 81).[4] In Los Angeles the County Library system experimented with the use of punched-card equipment for that purpose (MacQuarrie, 1984), and there was a similar effort in Seattle, at the King County Library System. While those efforts were essentially dead ends in the context of later developments, they were important steps in the general progress.

Information Science and Information Services

Given the requirements for information storage and access, focused especially in the intelligence community, computers were seen as a potential means for meeting them. Despite the limitations during this period the expectations were that the technologies would steadily improve; so there were many efforts to solve the technical and theoretical problems in this field. Indeed, my own company, Advanced Information Systems, was established precisely for that purpose, and by 1964 we had developed the first commercially successful database management system using the technical skills generated through research projects for the National Science Foundation, the Air Force, and other agencies.

But that was toward the end of the period. At the beginning of it the methods for information retrieval were largely based on physical matching of search criteria with document data. In this vein Calvin Mooers had developed Zatocoding as a means for using edge-notched cards, and Mortimer Taube had developed implementations of his Uniterm concept (Taube & Wooster, 1958; Taube, 1959).[5] The Intellofax system at the CIA did much the same thing, using punched-card equipment, and Hans Peter Luhn at IBM developed a similar set of approaches (Schultz, 1969).[6] In a real sense this focus on physical matching reflected the very nature of punched-card logical processing, which was based on direct connection by wires on a plugboard.

At that time even the attempts to apply computer technology to the tasks in retrieval started with physical matching, using optical coincidence, of search criteria with document data. In particular, the Rapid Selector (the realization by Ralph Shaw, at the National Agricultural Library, of Vannevar Bush's Memex) used optical matching. The Minicard system, developed by Eastman Kodak and the Magnavox Company for the intelligence community, similarly used optical matching. Even the Western Reserve "Searching Selector," developed by James W. Perry and Allen Kent, used an electronic counterpart of such matching (Becker & Hayes, 1963). The point is that those early developments had not yet recognized the capabilities of the computer for complex processing of recorded symbols, so it was not until the end of this period that the techniques of modern computer-based retrieval began to appear. On the other hand, it must be said that during even the early stages of this period many of the tools for complex information processing began to be developed. In fact, experiments in automated language translation were already under way by 1950, and they continued to be a major research investment until the end of the period.

One development toward the end of this period, made operationally possible by use of computer technologies, deserves special recognition. That was the creation of the *Science Citation Index* by Eugene Garfield and his associates at the Institute for Scientific Information (ISI). It truly revolutionized the means for indexing the literature of science, placing it in the hands of its users (Garfield, 1977).[7]

[4] In *Fifth annual report*, see especially pp. 28–41 (Report of the Assistant Secretary in charge of the library) and p. 81 (Report of the Commissioners upon the general catalogue).

[5] Taube and Wooster contains articles by H. P. Luhn, Calvin Mooers, Ralph Shaw, and others, as well as by Taube himself. *Emerging Solutions for Mechanizing the Storage and Retrieval of Information* contains a description by Luhn of the "IBM universal card scanner" that involved optical coincidence as the means for selection. Contains a variety of articles concerning coordinate indexing written by Taube and his associates.

[6] In Schultz, see especially "The IBM electronic information searching system," pp. 35–51 and "Information retrieval through row-by-row scanning on the IBM 101 electronic statistical machine," pp. 164–185.

[7] In Garfield, see especially Weinstock, Melvin, "Citation indexes," pp. 188–195 (reprinted from *Encyclopedia of library and information science, vol. 5*, pp. 16–40. New York: Marcel Dekker, 1971.)

1964 to 1980

At the beginning of this second period I joined the faculty of the School of Library Service, at UCLA. I almost immediately became director of the University-wide Institute for Library Research, the special objective of which was to explore the issues involved in developing automation in libraries and especially in academic libraries, such as those of the University of California. During the middle of the period I took a brief leave from the university to return to the commercial sector. Joseph Becker and I founded Becker & Hayes, Inc., to provide consulting services in the development of library automation, with special emphasis on its use in library networks (such as that of Washington State). We were later acquired by the publisher John Wiley and Sons and for some time published a series of books in the field of automation and information science.

The Scientific, Social, Economic, and Political Context

In retrospect, although it was not evident at the time, there was a steady reduction in the cold war conflict between the United States and the Soviet Union. The tensions were still there, and the cold war conflict would periodically bubble up and then simmer down. But the focus moved on to Vietnam and a real war, one that was insanity on our part and that may have virtually destroyed our society. As I recall, the cold war tensions were no longer the driving force for developments in our field.

In fact, something far more fundamental and ultimately revolutionary had become the driving force. That was the transition of the United States and, at a much slower pace, other industrialized countries from being "industrial" economies to being "information" economies. Today we see the impact of that transition in its effect on every component of our economy and our society, but it was during this period that the changes became evident. The report by Marc Porat on the information economy of the United States clearly identified what was happening and the fact that by the mid–1970s over 50 percent of the nation's workforce was engaged in information work (Porat, 1977).

Although many equate the appearance of the information economy as something created and driven by information technology, in my view the cause is more fundamental. It is the imperative in societal development that has created what we see, and the technology merely feeds and serves that imperative, making it possible but not causing it. In any event it is the fact of the information economy, whatever the cause, that was the driving force for developments in our field during this period. These perceptions led to the belief by some that there should be formal recognition of the need for a "national information policy" in the United States ("National information policy," 1976). Several other countries had already begun to develop national information policies, not least among them Japan, which made this a major priority for its Ministry of International Trade and Industry.

The importance of science information continued to be recognized. The Department of Commerce established the National Technical Information Service (NTIS) as one means to improve dissemination of scientific and technical information. The National Academy of Sciences repeatedly reviewed the status of developments and recommended increased efforts ("Science information activities," 1965; Committee on Scientific and Technical Communication, 1969).

From the standpoint of scientific information, the dominance of the United States, so evident during the previous period, began to dissipate. Several countries established scientific and technical information centers to coordinate national access to worldwide scientific information. I think especially of the Japanese Information Center for Science and Technology (JICST), in Japan, but there were similar developments in Taiwan, Saudi Arabia, and elsewhere (Hayes, 1972). By the end of the period the United States produced less than 40 percent of the world's scientific publication, and the rate of decline appeared to be about 3 percent per decade (National Science Board, 1989, p. 327).

Commercial, Industrial, and Consumer Context

During this period the importance of information began to be recognized by commercial and industrial companies. They began to install centralized management information systems and to experiment with access to external databases. While the level of information use was still small in comparison with today, it was clearly growing.

Among the developments during this period were several that paralleled those in information science. They were systems that provided online access to a variety of commercial databases, such as those for checking the credit status of individuals and organizations ("Survey of credit card verification systems," 1971), those for airline reservations management,[8] and those for stock market

[8] The Saber system, developed by American Airlines and still operative today, comes to mind.

quotations. The Quotron system was an early example of the latter, and it is still operating today on the Internet. The technologies involved, combining as they did computers with telecommunications, were essentially the same as those for reference database access services. The software, though, was different because it involved much simpler record structures and simpler retrieval criteria, but far greater numbers of transactions, by orders of magnitude.

The consumer use of information was also one of growth, especially for the various entertainment media—movies, network and cable TV, and sports. From 1964 through 1980 expenditures for consumer information quadrupled, increasing from $20 billion to $80 billion per annum. Of that, sales of leisure books, newspapers, and magazines also quadrupled, from about $ 10 billion to $40 billion.

Information Technology

During most of this period computing was centered on large mainframe computers. In fact, what was called "Grosch's law" (named after Herbert R. J. Grosch, who formulated it) governed most of the decisions about computing installation (Orr, 1968, p. 152). It states that "computing power goes up as the square of the cost," the implication of which is crystal clear: The bigger the better! During this period the California state legislature became committed to that view and attempted to force the University of California to use a single computing center to serve all nine campuses. The MELVYL system (named in honor of Melvyl Dewey of the Dewey Decimal System) was initially visualized as a centralized university-wide online catalog in the spirit of Grosch's law.

In parallel, there was extensive development of networks among computers, starting from the work of the UCLA Western Data Processing Center (the first such network) and expanding into ARPANET, of the Department of Defense, and the NSF's supercomputer network. Together they became the backbone of today's Internet (now supplemented by all of the commercial communication networks). These computer networks were made operationally feasible by implementing satellite and fiber-optic communication systems and by developing packet switching to break messages into pieces that could be sent independently by the fastest paths through the network and then reassembled at their destinations.

Publishing

During this period the processes of publishing were revolutionized, as computer-based photocomposition completely replaced the former manual methods. Xerography became a fact of daily life in business of every kind. From the standpoint of this history, though, the important development in publishing was the onset of electronic formats. The beginning was the creation of databases, initially as a result of efforts by the U.S. federal government.

The Library Context

During this period efforts increased to establish cooperative networks among libraries—not so much in the form of communication networks as in the form of administrative networks. Each of the states, under the stimulus of the Library Services and Construction Act, created its own multi-type state library network. The National Library of Medicine, under the mandate of the Medical Library Services Act, created the regional medical library system as a network. A variety of other networks were formed among groups of other types of libraries, especially academic ones. I recall especially the "Harvard-Yale-Columbia Medical Libraries" partnership that gave Fred Kilgour the springboard from which he created the Online Computer Library Center (OCLC) (Kilgour, 1984).[9] Indeed, this effort at cooperation reflected the generic issue of retrospective conversion of catalog records, which became a dominant concern of the academic library community. It was the reason for creating both OCLC and the Research Library Network as competing answers.

Cooperation in the area of cataloging was made possible only because of the crucial contribution of Henriette Avram at the Library of Congress in establishing the MARC (machine readable cataloging) format as the de facto national standard for exchange of catalog data. Without that it would have been intolerably difficult (Avram, Knapp & Rather, 1968; Avram, 1968; Avram, 1975).

Internal Technical Processing

It is in this area that perhaps the most dramatic change took place within this period. With the stimulus of the MARC format and the use of OCLC and the Research Libraries Information Network (RLIN) as economic solutions to the catalog conversion task, systems to

[9] In Kilgour, see especially pp. 235–238, 265–270, and 309–314.

support cataloging could be developed within institutions. At least a couple of them—DOBIS, developed at Dortmund University in Germany, and NOTIS, developed at Northwestern University in Illinois—became commercial products.

In parallel, modules were developed to provide other aspects of internal technical services—circulation and collection management, serial records, and acquisitions.

Information Sciences and Services

The major activities during this period are so well presented in the *Annual Review of Information Science and Technology* that I am not going to do more than highlight what to me were some of the most significant of them (Cuadra, 1966–present).[10] First, as a result of all that had occurred during the first period, the production and distribution of databases became a reality rather than merely a speculation. All of the research and technical development had come to fruition, and with great success. Of special importance were the online services (DIALOG, for example) for access to the reference databases (such as Chemical Abstract Services, Educational Resources Information Center [ERIC] , and MEDLINE) and library OPACs (online public access catalogs) for access to catalog databases. Less dramatic but still important was the implementation of interlibrary loan (ILL) services by OCLC and RLIN.

Second, beyond these operational developments were the academic ones, as information science became part of university education. At the end of the previous period there was discussion of the need for educational programs in science information and information science (Crosland, 1962; Goldwyn & Rees, 1965). At the beginning of this period persons who had been in industry joined library schools and introduced information science into the professional curriculum. For example, I joined the School of Library Service at UCLA, Don Swanson that at Chicago, Allen Kent and James Perry that at Western Reserve, and later Allen Kent that at Pittsburgh. At the same time programs in computer science were established, most in engineering schools but a few in departments of mathematics, and many of them incorporated elements of information science into their curricula. Schools of management later implemented programs in management information systems, again many of which also incorporated information science.

At the time none of these educational programs was unequivocally accepted as academically legitimate. I can recall the debates in 1966 when I served as chair of the Academic Senate committee that assessed whether a computer science department should be established at UCLA. The initial view of some on the committee was that computer science really was not an academic discipline worthy of separate recognition. Fortunately, the case was well made, and the decision was unanimously in favor. But it did require argument.

Third, at least at the beginning of this period, there were many discussions and in some cases explorations of alternative ways of providing science information services, related to and to varying extents dependent on the methods being developed in information science, but involving rather different kinds of approaches. Among them were recommendations that a national agency should be established to be responsible for coordination of science information, even perhaps modeled on the Soviet system embodied in VINITI (All-Soviet Institute for Scientific and Technical Information); fortunately, the pluralistic approach that characterizes the United States prevailed (National Information Center, 1963).

Others involved efforts to build upon, support, and use the "invisible colleges." Those efforts became quite controversial at the time and were abandoned, as such. But today they have been realized through the Internet in the various "list-servs" that support such direct and immediate peer-to-peer communication. Related approaches involved discipline-specific efforts like those of the Biological Science Communication Project (Janaske, 1962; Hattery, 1961). Perhaps the most significant and long-lasting of them were the several discipline-specific information centers that served as focal points for review and analysis of literature relevant to current research ("Management of information analysis centers," 1972). I think especially of the ones established by the National Institutes of Health, among them the Brain Information Service at UCLA; of the National Standard Reference Data Center at the then–National Bureau of Standards (Brady, 1968; Rossmassler, 1972); and of the several ERIC Clearinghouses (Burchinell, 1967).

Repeatedly, from the beginning of the 1960s to the present, congressional committees have reviewed the status of all of these experiments, and the related reports are excellent sources for perspective on the relevant history ("Documentation, indexing, and retrieval," 1960; "Documentation, indexing, and retrieval," 1961;

[10] The successive volumes of the Cuadra review cover not only the essential developments but provide a picture of the changing emphases in research and development in the field each year.

"Interagency coordination of information," 1962; "Scientific and technical information (STI) activities," 1978; "Information and telecommunications," 1981).

1980 to 1998

The Scientific, Social, Economic, and Political Context

This has been a most remarkable eighteen years! We saw the end of the cold war with the collapse of the Soviet empire, which led to the disintegration of other federations—Yugoslavia and Czechoslovakia, in particular. Those two for me were special shocks, since I had developed close ties with each of them.

The effects of these international events for our field are less tangible perhaps, but they are very real. The separate republics of the former Soviet Union became independent countries, each of which will need to deal with the information revolution. Beyond them other countries of central and eastern Europe that had functioned under the stultifying effects of Soviet-style communism face similar needs.

In the United States the continued progress in development of the Internet led the Clinton administration to identify the need for a national and then international "global information infrastructure." For the first time "information" beyond simply science information had become an explicitly identified priority in national policy (Clinton & Gore, 1992; "NTIA infrastructure report," 1991).

Commercial, Industrial, and Consumer Context

This period has seen a virtual revolution in the extent to which information resources are used throughout the United States. Today massive amounts of data are generated, transmitted, and consumed. The cellular telephone is ubiquitous, even in central and eastern Europe, where it serves as a substitute for the lack of adequate telecommunication infrastructure for the nongovernmental economy. The Internet and World Wide Web are growing in use at a phenomenal rate—doubling every three to six months. The entertainment and amusement industries are exploding. The publishing of books and magazines has grown similarly. Indeed, the "super bookstores" proliferate at an almost unbelievable rate, and one of the success stories of the Internet is amazon.com, an online bookstore.

Within companies, management information systems now function as decentralized services that bring data directly to the point of immediate need. Communication within companies and with their customers invariably starts with bringing up a display of an appropriate record from a file. The use of the Internet and its services brings external data directly into the process of decision making. For the consumer the picture is comparable. Today online banking from the home is a fact of life, and the use of credit cards in every commercial venue is commonplace.

Information Technology

You will recall that during the first thirty years or so of this history the decisions concerning computer acquisition were based largely on Grosch's law: Bigger is better! But something happened toward the end of the 1980s that was a fundamental revolution. The microcomputer—the PC and the Macintosh—totally reversed the law: Smaller is better! The new law is "Moore's law" (named after Gordon Moore, cofounder of Intel), which states that the capabilities of microprocessors double every two years (Moore, 1965). The result is that today, as I said before, I can hold in the palm of my hand more computing power than even the largest of mainframes had two decades ago. The result has been a distribution of computing power that puts the PC, laptop, or palmtop in the plane seat, the police car, the fire engine, the personal auto, as well as in virtually every home and office.

The revolution in information technology is far greater than just the computer itself, though the computer is indeed the centerpiece. Increases in telecommunication capacity in some respects equal those in computer capacity. Whereas fifty years ago we were limited to ten characters per second (roughly the equivalent of 100 baud), today we have data rates five hundred times greater for use in our own homes. Whereas forty years ago we had CRTs with minimal capability, today we have SVGA displays with resolutions virtually the equivalent of the printed page and screen capacities that permit the most beautiful images imaginable and the ability to observe in real time the operation of the heart or the brain of a human being, in living color. Whereas fifty years ago we were happy to have 6,000 bytes of internal memory, today we can have almost unlimited numbers of megabytes. And whereas thirty years ago the means for mass storage of data were limited in capacity and unbelievably slow, today we have gigabytes of capacity with rapid random access.

What a revolution it has been!

Publishing

During this period publishing has continued essentially unchanged, though with steadily increasing concern about how best to deal with the impact of electronic formats.

The Library Context

Turning to the library context in the United States, the major effect of our virtual bankruptcy resulting from the huge commitment of resources to military buildup has been the economic pressures on any and every public enterprise, among which are libraries. The funding problems for both public and academic libraries have been real and in some cases catastrophic. University libraries experienced 10 to 20 percent budget reductions each year for five years and more. The price of materials skyrocketed; journals in particular escalated in cost at 15 to 20 percent a year over the past decade.

Yet, in the face of the economic travails, the use of libraries has grown dramatically, for both public and academic libraries. The information economy requires the kinds of resources and means for information access that libraries and only libraries provide.

Internal Technical Processing

During this period the bits and pieces that were created by individual institutions have been replaced by integrated library systems, commercially available and with the support of highly qualified professional staffs. They are operational on both mainframes and personal computers; they function in both stand-alone and "client-server" modes; they will serve every type and size of library; they will function well in any country of the world.

When I think back to thirty years ago, I recall an article written by Ellsworth Mason. Titled "The Great Gas-Bubble Prick't," it treated the use of computers in libraries as a con game of the computer enthusiasts (Mason, 1971). During the weeks after it was published, my colleagues on the faculty of the library school would gleefully mutter, "The emperor's clothes, hee, hee, hee!" as they passed me in the hall. The interesting thing is that, in my correspondence with Mason before he wrote that article, I cautioned him about the costs involved in automation and about the difficulties and uncertainties (Hayes & Mason, 1971). But I also stressed the values that it would have in the increased services available to the users. That is the reason for libraries and that is what automation provides. All else is but froth.

Information Sciences and Services

The effects on information science and information services have been dramatic. The availability of OPACs in virtually every library makes the resources of the library and, in most cases, of the world readily available. The availability of CD-ROMs brings a wealth of materials into the library, not only available but in processible form. The Internet and the World Wide Web provide means for online communication and access that are changing the entire information economy.

1999 to 2005

It is difficult to make predictions, especially about the future, but I am going to do so by adding a fourth period—the coming five years rather than more—to those I have already discussed.

The Social, Economic and Political Context

I predict that the revolution that has resulted in the "information economy" will continue and that the pace will accelerate rather than decelerate, at least in other countries if not in the United States. The fact is information products and services have become a worldwide phenomenon. It has been estimated to be a trillion-dollar market, and the United States is the dominant supplier. The Internet and World Wide Web are simply a manifestation of it. The entertainment industry is without doubt the major component, and computer-related software and information packages are of increasing importance.

The reason I predict that this phenomenon will continue to increase is both simple and complex. The simple fact is that it has become easy to create information-based products and services. As the basis for doing so grows, the capabilities increase exponentially, and new products provide the basis for newer ones. The more complex fact is that creating information products and services consumes almost no physical resources; this means that it is not only easy but also highly economical to do so. One can create a product or service with almost no investment, except one's time, and easily test the market for it at minimal risk.

Of course, to do so depends upon both technological infrastructures—the telecommunications systems and the availability of inexpensive computers—and the capability to use them. That means that societies and countries without that infrastructure and those skills will be less able to participate in the growth. The gap between the "haves" and the "have-nots" will grow, not decrease.

Furthermore, none of the information technologies in themselves will solve the fundamental problems of overpopulation or the irrationalities of intolerance and hatred. Much though I wish it were otherwise, we will continue to see all of the evils that have characterized inhumanity.

Commerce, Industry, and Consumers

So what is going to happen to the use of information in commerce, in industry, and by the consumer? Frankly, awesome though the implications are, I think it will continue to grow as it has for the past period.

Information Technology

During the fifty years that I have been in the computer business, it has continued to grow at a phenomenal rate. Each year the capabilities have increased, the effectiveness and even efficiency have increased, and the pervasiveness in our society has increased. Of that fifty-year history, though, the most spectacular gains have been made within the past twenty-five when microprocessors—computers on chips—became the basis for the hardware. The first microprocessors were breathtaking innovations, and they revolutionized not only the design of computers but also their use throughout the world.

Will the process continue? In a recent book Michael Malone poses that question and concludes that the answer is "yes," saying that while there are absolute barriers in the laws of physics, there are still means by which the process can continue (Malone, 1998). Most important among them are those that relate to the software, in which future developments may have even greater impact than we have seen to date from the hardware.

Publishing

What is the future of publishing, especially in light of what is happening with the information technologies? In particular, what will happen to publication in print formats? Let us look at the means for electronic publication.

First among them is the Internet and the World Wide Web. The Web in particular is a phenomenon that has almost literally exploded within the past four to five years. Indeed, Web use is growing exponentially, doubling every three to six months. That pace in growth is likely to continue for the next two years, though with the likelihood of significant slowing after that. Future increases in these services and uses, however, will be highly commercial, with advertising playing an increasing role and such uses as pornography being among the most evident (as they were with the French MINITEL service). The Internet, highly academic in its origins and orientation, while growing, is doing so at a substantially more limited rate and is already very small in comparison to the Web. Access to the Internet will continue to be important for its essentially academic roles (such as scholarly e-mail and search of library catalogs). For library planning it will be essential to control carefully the extent to which access to the Web consumes library resources, especially of time at terminals.

Currently, CD-ROM is the fastest growing form of publication, doubling in sales every two years. While it may soon be displaced by DVD (digital video disk), the trends will continue and be similar. A similar rate of increase is likely to continue for the coming ten-year period, though with a steady leveling over time. In the past publications of importance to libraries have been of reference materials (indexes, abstracts, encyclopedias, data collections, etc.), which typically are made available through the CD-ROM local area network; those publications are likely to level off quite rapidly. The substantial increases will be in instructional materials, especially as represented by multimedia packages; in journals, especially scientific journals; and perhaps in other types of material. For purposes of general reading, however, this form of electronic publication is unlikely to displace the printed book or popular journal. Therefore, for library planning, it is necessary to plan for continued acquisition of materials in print form.

Electronic document delivery is a reality today, as represented by the commercial services that provide it as a replacement for interlibrary lending as well as for its own values in speed of delivery. It is also represented by a few existing journals. For example, some newspapers are already distributing Web versions of their materials. Some popular journals are likely to begin to appear through the Web, if they have not done so already. OCLC is publishing several scholarly journals online, such as the *Journal of Current Clinical Trials.* A variety of online communications on the Internet effectively serve as journals for limited groups. In the future general scholarly journals, especially those produced by commercial publishers, are likely to shift from current print publication of issues to future on-demand publication of articles. Print versions may even disappear. Other serial publications, such as conference proceedings, are also likely to be distributed in online form (as well as in CD-ROM format). There are no data for projecting the pace at which this will happen, however.

While there is clear evidence for a shift in journal publication from printed issues to on-demand publication of articles, there is no evidence of comparable shift of monograph publication in the same way. And even though newspapers and popular journals are likely to publish online versions, distributed through the Web, they will continue to publish their print versions. As with CD-ROM materials, therefore, for purposes of general reading, online electronic publication is unlikely to displace the printed book or popular journal. Again, for library planning, it is necessary to plan for continued acquisition of materials in print form.[11]

Digitized imaging is a form of publication that will be of increasing importance in specific areas. It has become a powerful tool in research of all kinds. It is the basis for publishing of such materials as maps and may well replace print. Academic libraries in particular should plan for management of digitized images.

Libraries

What will happen to libraries? There are persons who forecast their demise in the perception that they will be replaced by the wealth of resources becoming available through the information technologies; such voices have been heard for at least the past three to four decades. It is a fact that during the past decade libraries have faced enormous economic pressures; they have had to operate within the constraints of reduced budgets at the same time that the costs of acquisitions, especially of journals, have been escalating. At the same time they have needed to make continuing investments in automated systems and to deal with the array of computer-based forms of publication.

My own perception, though, is very different from that of those who wish to get rid of libraries. My view is that libraries are essential and will continue to be so in the foreseeable future. Instead of being overwhelmed by technologies, they have absorbed them, made them economic and effective, and served as the basis for testing and proving them. It is also a fact that the use of libraries of every type has been increasing, not decreasing. Indeed, a study at Columbia University showed that the effect of electronic information resources was to increase not decrease the use of the library. The various forms of publication are complementary and mutually supportive rather than being substitutes for each other. The use of any of them leads to increased use of the others, and the library serves as the agency for access to all of them.

I have every expectation that the library will continue not only to exist but to thrive and to play its historic leadership role in the coming decades. Underlying that expectation is my view that, while electronic publication will be increasingly important, it will not replace print in the foreseeable future. And libraries will be the means of access to both print and electronic formats.

Library Automation

My perception of internal technical processing is that the dramatic changes resulting from automation have already occurred and that the future will not significantly add to them. The bibliographic utilities, OCLC especially, are well-established, economically viable operations; their scope of coverage is becoming increasingly international. Cataloging and acquisitions work can depend upon their online union catalogs (OLUC, as OCLC refers to it).

Having said that, it is likely that there will be a steady shift to outsourcing of cataloging and even of acquisitions work, at least within smaller academic and public libraries. (For the special libraries that serve business and industry, it is already a fact of life, and they really function primarily as a means for access to information rather than as collections of materials.)

The implications are that library services to patrons will become increasingly important and that staff will be shifted from internal operations to direct services.

Information Sciences and Services

What will happen to information science and information services? The crucial point to me is that the widening scope of information resources increases the importance of both the science and the services. In this respect we should recognize that the library is more than simply a collection of materials, valuable though that is and will continue to be. It is also more than simply a means for access to those materials and the information contained in them, again valuable though that is and will continue to be. The library is the agency that serves as the means for selection. It does so when acquisition librarians make decisions about what materials are worth adding to the collection. It does so when reference librarians help patrons in locating and selecting from the wealth of resources those that will meet needs. It does so when library-based information specialists select from retrieved information and analyze the results.

The library is also a means for users to learn how to manage information resources. Library services in teaching are therefore of special significance, and the increasing wealth of resources adds greatly to their importance.

[11] See, for example, Textbook case: publishers look to cash in on rising demand for books, *Barron's*, 7 Dec 98: “Experts predict that elementary and high school textbook sales will jump by 35%, to $3.5 billion, from 1996 through 2001. College textbook sales are expected to zoom 40%, to $3.47 billion, over the same span.” (http://www.smithbarney.com/cgi-bin/bench)

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