Microfilm Technology and Information Systems

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Abstract

This paper explores the ways in which the use of microfilm served as a precursor to later computerized information systems in business, education, and science. This accessible and inexpensive photographic technology allowed scientists, scholars, and others to experiment with ideas for information storage and retrieval that were not ultimately realized until the 1990s.

In 1926, George McCarthy, vice president of a New York bank, invented a rotary microfilm camera for copying bank checks automatically. This camera paved the way for the microfilm industry to record large volumes of documents very rapidly. Microfilm was quickly adopted by banks in the 1930s and by other businesses, industries, and government agencies.

Libraries, eager to expand access to resources required by a burgeoning research community, also adopted microfilm. Although academic enthusiasts predicted that microfilm would revolutionize scholarship, the limitations of reading machinery precluded an unmitigated success. Users in academia, business, technology, and science also sought to improve on the ways in which data could be retrieved from microfilm. This paper discusses three specific attempts to overcome output limitations: the struggle for good reading machines; the pursuit of more standardized and sortable formats, i.e., microcards and aperture cards; and finally the use of microfilm as an expendable element in new computerized information systems.

Introduction

Microfilm served as a precursor to and a component of computer-based information systems in business, education, and science. From microfilm's inception as a modern industry in the late 1920s, its proponents extolled its virtues as a solution to many difficult problems in information acquisition, storage, duplication, and retrieval. Sometimes they envisioned it as a complete information system that would revolutionize education, libraries, and the process of scholarly and scientific publication. At a minimum, this highly accessible and inexpensive photographic technology allowed scientists, scholars, and others to "experiment" with ideas for information systems that were only fully realized in the 1990s.

Although microfilm failed to fulfill the loftier visions of its potential, attempts to overcome its limitations as an information medium demonstrate that users wanted more sophisticated information systems. Buckland (1992) and Burke (1994), among others, have documented some of the early attempts at microfilm-based automated information systems. After examining the general social context out of which microfilm's use arose in business, education, and research in the 1930s, this paper discusses three specific attempts to overcome these limitations: the struggle for good reading machines; the pursuit of more standardized and sortable formats, i.e., microcards and aperture cards; and finally the use of microfilm as an expendable element in new computerized information systems.

The term *microfilm* is used here interchangeably with the more comprehensive *microform,* acknowledging that there are many variations on the classic roll microfilm. However, in our context, the term microfilm can conveniently represent all of them except where specifically indicated otherwise. Based on Michael Buckland's exploration of the multiple meanings of information and information systems, microfilm clearly qualifies as an integral part of an information system. In *Information and Information Systems* Buckland (1991) calls for information systems to be broadly defined so that they include a larger universe than the computerized information retrieval systems with which they are sometimes equated. Information systems encompass the selection, storage, retrieval, and output of information. It was the unique ability of microfilm to store large amounts of information inexpensively and for the long term—literally hundreds of years—that attracted users to microfilm in the early twentieth century.

Microfilm in Business and Industry

Microphotography had been invented in 1839 but served primarily as a curiosity for more than seventy-five years. During that period it evolved and improved. By the early twentieth century the push of this advancing photographic technology, readily available even to amateurs in the form of snapshot and home-movie cameras, was augmented by the market pull of large bureaucratic organizations generating ever-increasing quantities of paper documents. The style, quantity, and technology of communication within large business organizations changed dramatically between the mid-nineteenth century and 1920. Managers required frequent, structured written reports and data from their underlings, while executives and supervisors instituted circulars and in-house magazines to communicate downward to subordinates. JoAnne Yates (1989) posits the emergence of a modern system of internal communication as a tool of managerial control. Emerging office technologies, such as the typewriter, duplicating equipment, and vertical filing cabinets, supported this increased activity. Companies expended substantial resources to create, duplicate, file, and store written documents originating inside and outside their businesses; the management of these large volumes of written documents became increasingly difficult.

On the consumer side of the business equation, real income growth, a flourishing advertising industry, such new products as the automobile and radio, and the introduction of installment buying created steady growth, all of which contributed to a dramatic increase in business recordkeeping. Banks promoted checking accounts widely in the early twentieth century, even to industrial workers. But by the late 1920s many banks found the cost of servicing these small accounts so high that they considered instituting service charges (Klebaner, 1990). Among these costs was tracing every check through the banking "transit" system. A 1923 banking textbook noted, "It is essential in banking practice to be able to trace every check handled. It would be ideal to have a photograph of all checks received but manifestly impossible" (Kniffin, 1923, p. 354).

As if in response to this plea, in 1926, George McCarthy, vice president of a New York bank, invented a rotary microfilm camera for copying large volumes of bank checks automatically. Soon thereafter McCarthy granted rights to his invention to the Eastman Kodak Company in return for the presidency of Recordak, a new division created to manufacture and market microfilm cameras. Microfilm was quickly adopted by banks in the 1930s and more gradually by other businesses and industries.

Microfilm in Academia and Science

Interest in microfilm spread to various loosely related nonprofit sectors: the scholarly and scientific communities, research libraries, and government and archival agencies. Libraries, anxious to expand access to resources required by a burgeoning research community, wholeheartedly adopted microfilm. The expansion of library collections has always been a source of pride and competitiveness among institutions of higher education. During the 1920s and early 1930s this competition was intense among major universities, escalating to a sort of intellectual arms race. Faculty and librarians alike knew the stakes. Addressing an audience of alumni, Professor Chauncey Brewster Tinker (1953) of Yale called for action at his institution in these terms:

> If you want your sons and brothers well taught you must have teachers here who are men and learned men; if you are to keep learned men here, you must have a still and quiet place for them to read and think in; but, above all, you must have books for them—not merely a standardized fifty-thousand foot shelf, warranted sufficient for running a university, but a library of millions of volumes, with strange books in it, out-of-the-way books, rare books and expensive books. If we are not willing to compete with the best libraries in this country, it is folly for us to attempt to be one of the great universities, for scholars and teachers, graduate students and at last, undergraduate students will go where the books are. (P. 89)

The output of science and social science research not only added to the pressures on libraries, but also produced a crisis in scholarly communication as delays in the publication of journal articles increased. A diverse company of librarians, archivists, scientists, scholars, philanthropists, and entrepreneurs envisioned microfilm as a partial solution to these problems. Librarians wrote about microfilm, served on professional committees related to microfilm, and attended conferences devoted to microfilm. The tone and volume of this literature reminds one of the early days of computing technology in libraries and even involved some of the same individuals. In 1940, Fred Kilgour, a young assistant at the Harvard University Libraries, wrote in an article for the

Christian Science Monitor that microphotography was "one of the most important developments in the transmission of the printed word since Gutenberg" (Kilgour, 1940, pp. 8–9).

Watson Davis, second director of Science Service, was influential in using microfilm to disseminate scientific and technical journal literature. Founded in 1920 as a nonprofit news syndicate and funded by the Scripps Foundation, Science Service was governed by a board composed of representatives of the American Association for the Advancement of Science, the National Academy of Science, the National Research Council, the E. W. Scripps estate, and the journalism profession. Its mission was to publicize science in the popular press to build support for the continued funding of scientific research that scientists feared would decline with the end of World War I. After he became director in 1933, Davis aggressively pursued his special interest: facilitation of the delivery, publication, and bibliography of scientific literature via microphotography. Inspired by the European-based documentation movement, he adopted as his goal the production and maintenance of "A World Bibliography of Scientific Literature." Exposure to influential librarians, scientists, and inventors in Washington, D.C., provided a personal network and increased his familiarity with both microfilm technology and bibliographic work.

With a $15,000 grant from the American Chemical Society, and the reluctant permission of the Science Service Board, he initiated the Documentation Division of Science Service in 1935 with three projects: operation of the BiblioFilm Service already begun under the auspices of the National Library of Agriculture; development of suitable microfilm cameras and readers to be designed by Navy Lieutenant Rupert Draeger; and microfilm publication of scientific literature by a new entity called the Auxiliary Publication Service.

Because the skeptical Science Service executive committee had specifically limited the subsidy of the new Documentation Division to only fifteen months, Davis acted quickly to ensure its continued existence. He staged a prestigious invitational conference on documentation in January 1937 and orchestrated a call for an organizational meeting to found the American Documentation Institute (ADI). Thus, on 13 March 1937, through his vision and determination, Watson Davis served as midwife to the birth of the American Documentation Institute, the direct predecessor of the American Society for Information Science. He moved the Science Service Documentation Division microfilm activities to ADI. In her book, Irene Farkas-Conn (1989) traces this history in detail.

Other individuals, notably Robert Binkley, Eugene Power, and Vernon Tate contributed to the growth of microfilm in the scholarly world. Professor Binkley, who served as chairman of the Joint Committee (of the Social Science Research Council and the American Council of Learned Societies) on Materials for Research, did an exhaustive study of the efficiency of microfilm as a medium for scholarly publication. His book-length report provides detailed descriptions and actual examples of the film and duplicating technologies of the time; unfortunately his assertions that microfilm could solve the economic problems of scholarly publishing was impaired by his underestimation of the high fixed costs of editorial work that persist in film (and electronic) publication (Binkley, 1936). Eugene Power founded University Microfilm Inc. (UMI) and with the cooperation of large research libraries and foundations began microfilm publication of major research sets, periodicals, and dissertations. *Dissertation Abstracts* began as a free index to UMI's series of dissertations on film. Vernon Tate was deeply involved in almost every aspect of microfilm from the 1930s through the 1960s. First as chief of the National Archives Division of Photographic Resources and Research and then during his twenty-year career as director of libraries at Massachusetts Institute of Technology and the Naval Academy, Tate was instrumental in the founding and growth of the National Microfilm Association. He was heavily involved in several of the early attempts to improve microfilm as an information system by inventing a more acceptable microfilm reader.

The Search for an Acceptable Microfilm Reader

An information system is only as strong as its weakest link, and microfilm was especially weak in retrieving and outputting information to users. Retrieval of discrete information remains difficult on roll film, and, especially in the early days, care was not taken to film materials in a logical order to minimize this problem. So-called "unitized" microfilm (single-sheet film products like microfiche and microcards) with eye-readable headers and automated microfilm systems like Kodak's Miracode in the 1960s attempted to improve retrieval. But the most persistent and difficult problems were with output—the lack of easy-to-use reading machines and printers.

The academic and scientific communities spent decades fostering the design of affordable, comfortable readers without much success. In the 1930s Robert Binkley and others had cast the advancement of science and scholarship as at least partially dependent on widespread adoption of microfilm. Fostering such progress by supporting the development of microfilm technology was thus consistent with the goals of large foundations. The Rockefeller, Ford, and Carnegie foundations funded microfilm laboratories in research libraries and large microfilm publication projects. It seemed logical to enlist the help of the National Research Council, funded by several of the same foundations, to address technical problems relating to microfilm.

The National Research Council established a Committee on Scientific Aids to Learning as one of the technical committees directly under its executive board. James B. Conant, president of Harvard University, served as chairman, and the rest of the membership also was prestigious: Vannevar Bush, then vice president and dean of the School of Engineering at Massachusetts Institute of Technology; Frank B. Jewett, president of AT&T's Bell Laboratories; a well-known New York attorney; two university presidents; one professor, and the chairman of the National Research Council. The committee commissioned a report on the status of microphotography equipment and supplies, the development of specifications for a "student" microfilm reader, and an investigation into eye fatigue. Vernon Tate (1938) was selected to compile the report. Noting that "progress [on readers] has been painfully slow. Little selection is now possible," Tate (1939, p. 44) recommended that the committee assume responsibility for designing a reading device for the individual scholar. The committee did sponsor a competition for a low-cost reader, awarding a contract to the Spencer Lens Company of New York. This device proved inadequate in every way.

In the early days of microfilm some important technical problems with reading machines were solved; for instance, a rotating head was added to facilitate reading materials filmed at both cine and comic orientations. At least one manufacturer, International Filmbook, tried to lessen the high dexterity required for loading roll film into readers by placing the film in individual cassettes. Bankruptcy was Filmbook owner Verneur Pratt's reward for this useful but expensive innovation. Recordak responded to requirements for readers accommodating diverse microfilm formats by offering a variety of machines, including ones specifically designed for newspapers and large engineering drawings on microfilm. World War II interrupted the development cycle; indeed at that time most users were content to have access to any reading device at all, let alone a comfortable and convenient one, since many were requisitioned for the war effort.

Even in the 1960s librarians were still pursuing the low-cost individual portable reader through a project championed by Verner Clapp at the Council on Library Resources. That project floundered for many reasons, including the inability of the library community to standardize microfilm publications sufficiently. Procuring a good reader was a challenge at best; adding the requirement of a "universal reader" for all formats was truly hopeless. Writing to his life-long friend Eugene Power, Vernon Tate (1972) summed up the situation:

> *You* started out with Edwards Brothers in facsimile reprinting of early texts so that they could be made available for people to read. *I* pushed along in microfilm because it was the one way that I could acquire books and manuscripts that I *wanted to read.* One thing is lacking. Microfilm has claimed many adherents who have persuasive arguments for its use in myriad ways, but the truth is that no one wants to read it, really, and it remains at best a substitute form "faut de mieux," and so while so much has been accomplished in some ways, so little has resulted in others.

Microcards: Creating a Standardized Microfilm Information System

Microcards represented another attempt by librarians and scientists to create more robust information systems better designed for retrieval and in a more uniform format. Microcards are opaque cards made of photographic paper, usually 3×5 inches in size, on which page images have been contact printed on both back and front from strips of 16-mm or 35-mm film arranged in rows and columns. Step and repeat cameras that automatically photograph and correctly place sequential pages of text onto the same piece of sheet film were used to film the cards; printing was accomplished by a process similar to consumer photofinishing (Kuipers, 1951). Production of these cards began in the late 1940s and continued into the 1960s when they were largely replaced by microfiche.

The inventor and leading advocate of microcards was Wesleyan University librarian Fremont Rider (1944), whose treatise, *The Scholar and the Future of the Research Library*, dramatized the impending space crisis confronting rapidly expanding research libraries. Rider postulated that the microcard would drastically reduce the four major costs of libraries (original purchase, storage, binding, and cataloging) by combining the catalog card with the reduced text itself contained on the back of the same card. Encouraged by brisk sales of his book, Rider convened a prestigious Microcard Committee composed of appointees of North American library associations and major research libraries. Chaired by Rider, the committee first discussed a centralized publication process and standardization of the microcard itself. Rider emphasized that "the vitally important thing seems to me to be that the library [community] would be able to control microcard standards and so be able to insist upon interfilable uniformity in all microcards" (Rider, 1945a, pp. 162–163). He attempted to put in place an elaborate structure that would ensure this result. A protégé of Melvil Dewey, he was described by one biographer (Parker, 1978) as "a man of singular purpose and enormous drive, not easy to work with and not likely to take note of opposition."

The Microcard Committee debated the feasibility of libraries controlling all aspects of this microformat: selection and physical assembly of items, bibliographical organization (i.e., cataloging), manufacture, and distribution. The group quickly realized that the purchase of capital equipment was beyond the scope of libraries, thus rendering some level of commercial development inevitable. Rider (1945b) hoped that libraries might still uphold these standards by their consumer behavior, since "all they would have to do would be steadfastly to refuse to buy any bastard format, non-standard cards that might be issued by any one." He was adamant that the "library world ought to try to 'direct' the microcarding movement" to avoid dominance by technology developed for other markets, as had so clearly been the case with roll film.

A corporate sponsor emerged swiftly to spearhead and finance the technological developments necessary for microcards, that is, readers and production equipment. Charles Gelatt, chief executive of the Wisconsin-based Northern Engraving and Manufacturing Company, was attracted by a *Time* magazine review of *The Future of the Scholar* and contacted Rider. Gelatt set up the Microcard Corporation in the mid-1940s, and he later formed Micro Library Inc. as a subsidiary to sell the readers and the equipment for producing microcards.

Since opaque materials required reflected rather than transmitted light for reading, reader design was particularly difficult, but several firms developed microcard readers. As of 1950 Rider reported that two readers had been completed: a large standard machine for $195 and a smaller portable machine for $162. By the mid-1960s combination microcard-microfiche readers became available but not combination reader-printers. As mentioned, during the mid-to-late 1950s, the Council on Library Resources financed a long but futile effort to develop a low-cost portable reader for the microcard. With the support of the Microcard Committee, Rider and Microcard Corporation executive Earl Richmond established the Microcard Foundation in Wisconsin in 1948 as a nonprofit organization to coordinate the publishing of materials on microcard. Fremont Rider served as the foundation's chairman from that time until his death in 1962. The foundation supervised the cataloging of microcards to be published to assure bibliographic accuracy acceptable to the library community.

Charles Gelatt had a broader vision for microcard publication than Fremont Rider did for obvious reasons of his commercial interests, and in 1952 his Microcard Corporation contracted to publish Atomic Energy Commission technical reports. Part of the AEC's mission was to disseminate scientific information generated by research into nuclear technology, usually in the form of technical reports. The Atomic Energy Act of 1946 included a directive that "the dissemination of scientific and technical information relating to atomic energy should be permitted and encouraged so as to provide that free exchange of ideas and criticism which is essential to scientific progress" (U.S. Statutes, 1946, p. 755). By 1950 AEC expenditures for research and development had exceeded $120 million, outrun only by Air Force and Navy outlays (Fry, 1953). The AEC Technical Information Service issued declassified wartime reports and unclassified reports of continuing research to the AEC's own laboratories, AEC contractors, and more than forty AEC depository libraries located primarily in major research universities. The Technical Information Center also performed other documentation services, including publication of the indexing and abstracting tool, *Nuclear Science Abstracts*, and the distribution of classified reports to many of the same organizations.

From 1952 to 1964, the AEC distributed twenty million microcards produced by the Microcard Corporation. Microcards were well suited to AEC requirements because individual reports could be more easily retrieved than on roll microfilm. In addition, AEC contractors that had to store classified reports in safes and vaults saved money because of the reduced size. Bernard Fry stated that his estimates were based on conversations with librarians and information officers of agencies; however, at the time of writing Fry himself had been connected with atomic energy research for nine years: initially as an intelligence and security officer for the Manhattan Project and since 1947 as chief librarian of the AEC Technical Information Service.

The Library of Congress Navy Research Section, which soon evolved into its Technical Information Division, issued technical reports on microcards. During the span of microcard production, other types of materials were published as well, including the University of Oregon–sponsored publication of dissertations in health, physical education, and recreation; the famous German chemical reference work *Bielstein*; and even a periodical, *Wildlife Disease,* published exclusively on microcard.

Two features of Rider's original proposal failed to develop as he had recommended in his early publications about the microcard. As noted, one was that the publication of microcards would be undertaken by libraries themselves and not by commercial organizations. The second was that microcards would be filed in the card catalog itself. This impractical approach was abandoned even at his own institution, where the reference librarian announced that "he [Rider] has since decided that ordinarily it is better to store a library's microcards in a separate file, representing them in the catalog with typewritten or L. C. catalog cards. . . . Certainly the removal of cards from a main catalog is never to be encouraged" (Bacon, 1958). Thus, although the rationale for producing cards in a 3×5 size disappeared, the standardization of microcards in this size stood firm, buttressed by the complex support structure established by Rider. The ultimate demise of microcards came not from "bastard formats" of the opaque card but from the revitalization of an older transparent format—sheet microfilm. Unfortunately, many libraries and information centers are still saddled today with almost inaccessible information on microcards, sad remnants of this failed attempt at an improved information system.

Aperture Cards: Sorting Graphical Data

The history of the microfilm format known as the aperture card demonstrates a way in which scientists and engineers developed information systems that would satisfy their needs for storing, sorting, retrieving, and displaying graphic materials, particularly engineering drawings. An aperture card is a device for storing and sorting microfilm copies of paper documents. A hole (aperture) cut in a card is covered and slightly overlapped by a protective glassine sheet adhering to thin strips of pressure sensitive tape around the hole. The glassine sheet is removed when a frame of microfilm is substituted. In a variation without the adhesive the film is suspended from a pocket formed by mounting thin sheets of polyester film on either side of the aperture, leaving one end of one sheet unsealed for the film insertion. Early aperture cards were sometimes mounted on McBee Keysort cards that could be notched on the margins to indicate an index term and then sorted manually with tools resembling knitting needles. In the most widespread application of the aperture card, the microfilm was mounted on an electronic data processing card that could be keypunched and machine sorted.

John F. Langan invented the aperture card while working as chief of the Pictorial Records Division of the Office of Strategic Services (OSS) during World War II. The OSS had appealed to citizens to send the agency any photographs of enemy and occupied Europe that might prove helpful in the war effort. The overwhelming response left the division awash in a sea of millions of bulky, nonstandard, unindexed pictures. In 1943 the agency implemented a system designed by Langan to microfilm the pictures and mount them on aperture cards, thereby reducing these variously sized units to one uniform 35-mm size and facilitating storage, indexing, and retrieval. Near the end of the war Langan filed a patent application for the cards, which was finally granted in June 1950. Failing to interest commercial parties readily in his invention, he sold his rights to two OSS colleagues: Colonel Atherton Richards, former deputy director, and William J. Casey, former chief of intelligence in Europe, and, later, CIA director in the Reagan administration. Richards and Casey incorporated Film 'N File, Inc., contracted with the Dexter Folder Company to manufacture equipment, and arranged distribution through the McBee Company.

A few business applications for aperture cards emerged. For instance, in 1947, the St. Louis Police Department mounted mug shots of criminals on the Film 'N File product. A young Utah engineer designed an effective camera and viewing device for a microfilm aperture card system that was installed in more than fifty real estate title and abstract companies mostly in the western United States. In 1949 Arthur H. Rau of General Electric's engineering division recommended that the cards be used for the storage and retrieval of engineering drawings. Rau estimated that GE alone would purchase millions of them.

In 1951 Film 'N File was renamed Filmsort, Inc., emphasizing the product's ability to manipulate information as well as store it and was acquired by the Dexter Folder Company. Dexter decided to market this product aggressively to the largest user of engineering drawings in the world, the United States government. After an unlikely start, selling the system to the Department of Agriculture for storing and retrieving photographs of meat labels, Filmsort sold heavily into the military—the Air Force, the Army Signal Corps, and the Navy. The services had all used roll microfilm to make archival security copies of engineering drawings, but with the onset of the Korean War they began investigating an integrated system that would dispense with paper drawings altogether in the day-to-day work environment. To illustrate the economy of this approach, the Army Signal Equipment Supply Agency cited its comparison of the same operation of retrieval and refiling of a thousand paper engineering drawings (more than sixteen hours) with the aperture cards (less than five hours) (Davison, n.d.). The ease with which aperture cards could be duplicated facilitated distribution of card sets to multiple sites (satellite plants, technical libraries, vendors, or customers). In addition, multiple card sets filed in different sort orders (by number, by location, by type of machine) enhanced retrievability (Mann, 1976). The Navy contracted with Haloid Corporation for development of modified Copyflo printers to output paper drawings from the microfilm as needed.

Major players in the microfilm and duplicating industries learned that aperture card systems were going to be widely adopted throughout the U.S. military. In the spring of 1954 Remington Rand, Diebold, and Recordak requested and received Filmsort distributorships so that their companies would be ready to supply the cards along with cameras, film, and processing services. In September 1954 Filmsort sponsored a meeting in New York City for the military services, current aperture card users, and suppliers to discuss standards. Participants in the meeting, including the military representatives, agreed that military specifications (standards) for aperture card systems were needed to encourage maximum compatibility between the card systems and supporting equipment. Like Fremont Rider, they understood that the proliferation of formats was potentially a major detriment to economy of operation.

As an outgrowth of this meeting the Department of Defense (DoD) formed its 0009 Committee, and for several years the major players (Navy, Air Force, Signal Corps, Central Intelligence Agency, Western Electric, Recordak, Remington Rand, IBM, Haloid, RCA Victor, Graphic Microfilm, and Filmsort) discussed features like reduction and enlargement ratios, frame sizes, and aperture locations (MacKay, 1966). Even before the final specifications were actually issued in April 1960 (MIL-STD-804, MIL-M-9868, and MIL-O-9878, all 1960 specifications relating to the production of aperture cards, covered sixty-five pages), the committee's work served to rationalize the aperture card and equipment industry by providing de facto standards. The 1961 National Microfilm Association Convention featured multiple sessions on the resulting DoD Defense Engineering Data Micro-reproduction System (EDMS or EDMS-0009) and in 1962 presented its annual award for outstanding achievement in microfilm to the DoD in recognition of this standardization.

In 1959 the Minnesota Mining and Manufacturing Company (3M) acquired Filmsort just as military and industrial use of aperture card systems expanded. The success of aperture card systems in automated information environments would have been seriously threatened if this acquisition had not taken place because, as machine manipulation of cards increased during the early 1960s, the Filmsort adhesive proved inadequate. The adhesive bled beyond the edge of the glassine cover causing the cards to stick together to such an extent that failure rates approaching 30 and 40 percent were common until 3M's adhesives group developed a new substance that eradicated this problem. Although 3M's acquisition of Filmsort was originally motivated by the match between product lines (aperture cards, mounting equipment, readers, and reader-printers), its core competency in adhesive technology cemented the relationship.

Over time many engineering firms, military agencies, contractors, and governmental units incorporated aperture card-based information systems into their operations. Large engineering systems combined the aperture card with the Xerox Copyflo printer. By 1960 numerous large projects were under way: Chrysler's Missile Division distributed more than three million aperture cards with engineering drawings for one of its missile programs; the Army's Redstone Arsenal converted a hundred thousand drawings to aperture cards; military contractor Raytheon Corporation microfilmed more than one million engineering drawings and documents under contract with NATO.

In its ideal application aperture card systems consisted of effective indexing systems, microphotographic technology, electronic card sorters (the workhorses of early data processing), and specialized printers. Users could retrieve individual cards or card sets based on index terms keypunched into the eighty-column card. Thus, the information itself in text or image was more closely linked than in previous systems. In actuality, many users seemed to gain significant benefits simply by maintaining manual filing systems of aperture cards in lieu of the unwieldy engineering drawings. Users may not have had convenient access to card sorters or they may have been discouraged by warnings about damaging cards. Successful card sorting required close tolerances and specialty adhesives—even IBM recommended that sorting be limited to occasional file maintenance. The location of the aperture in the Military D specifications was based on Remington Rand equipment rather than IBM card sorters because the DoD Committee felt this location maximized the space for keypunch data (Carroll, 1960).

Minimizing machine sorting reduced wear and tear on the somewhat fragile film and card systems. In addition, card "scruffing" occurred when the cards slid against each other in sorting equipment. It would be more than thirty years after the promulgation of military specifications for aperture cards and many, many generations hence in computer and telecommunications technology before electronic retrieval of graphic materials like engineering drawings would be achieved. 3M is still active in this market today supplying modern networks of engineering data available to users immediately on the shop floor.

Role Reversal: A Storage Technology Becomes an Output System

A final example of the part microfilm has played in the development of more modern computerized systems is one in which microfilm essentially reverses its role from that of permanent storage mechanism to serve as a temporary inexpensive substitute for paper in an automated environment. The installed base of computers slowly increased in business and industry throughout the late 1950s and then multiplied substantially with the introduction of the IBM 360 machine in the early 1960s. Weak components of computerized information systems became more apparent, and the purveyors of microfilm technology identified two niche technologies that would allow microfilm to serve a role in strengthening computerized systems. In one instance a microfilm innovation served as an input mechanism; in the other instance as an output mechanism. In both cases microfilm built not on its premiere strength as a medium that offered permanent storage but on its usefulness as an inexpensive medium.

The U.S. Census Bureau sponsored the development of microfilm as an input mechanism to a computerized information system. Indeed the Census Bureau's information processing systems beginning with Hollerith's punch card for the 1890 census offer a decennial snapshot of technological progress. In preparation for the 1960 census, Recordak designed specialized high-speed microfilm cameras to feed, flatten, and film coded census booklets at a high rate of speed. Flying spot scanners known as film optical sensing device(s) for input to computers (FOSDIC), developed by the Census Bureau in cooperation with the National Bureau of Standards, then read and recorded codes on the microfilmed documents onto magnetic tape for input into computer systems. The required data were captured and input into computers without extensive handling of paper forms or keypunching. If the spot scanners had to read the codes directly from the paper booklets, dust particles would have prevented the machinery from operating properly: Film was substituted for paper and then discarded.

The system was first used in 1960 and then improved for further use in the 1970 census. The U.S. Weather Bureau modified the FOSDIC system to scan microphotographs generated from three hundred million punch cards of weather information. In 1990 the Census Bureau was still microfilming questionnaires for processing, although FOSDIC itself had been replaced with more sophisticated technologies. Flying spot scanners were used subsequently in true optical character recognition applications, a more advanced version of the technology than detecting marks on microfilmed documents.

In the output niche technology computer-output-microform (COM) served as the medium for the distribution or publication of computer-generated data. The impetus for COM came largely from computer users and potential users frustrated by the slow output of voluminous paper reports. Many businesses believed that computers would not be practical for their applications until printer speeds were substantially improved. Arthur Andersen consultants admitted the gravity of this deficiency when reporting that "not only are the immediate manufacturers of computing equipment engaged in extensive and expensive programs of research designed to produce printers of such fantastically high speeds, but even manufacturers not concerned about the production of computers proper have become active in the development of high-speed printing equipment" (Higgins & Glickauf, 1954).

In COM technology a microfilm camera photographs text and graphic images generated by a computer and displayed on a specialized cathode ray tube (CRT). The CRT was invented in the late nineteenth century and further developed during the 1920s and 1930s for use in television. In the early 1940s the CRT was used by radar developers because it offered a display device with a sufficiently persistent image to compensate for the relatively slow revolution of radar antenna. After the war, defense contractor Stromberg-Carlson unveiled a specialized CRT christened the Charactron to serve as the display device for graphic and textual data generated at high speeds by the Air Force Early Warning System. In the mid-1950s Stromberg-Carlson harnessed its specially shaped tube to the computer at one end, for input of binary data, and to a microfilm camera at the other end for output from the CRT screen to film. Either an online computer link or a magnetic tape supplied the data to the system. A "form slide" was projected onto a mirror between the CRT screen and the camera to provide a template with the traditional row and column divisions and headings expected by report users, without requiring the form itself to be generated on the CRT.

Microfilm-based computer output could be generated at high speed and offered cost advantages over paper where reports or data were widely and frequently distributed, for example, weekly, monthly, or quarterly updates to multiple sites. Until the 1980s to 1990s data users were often not online, so these large outputs were required frequently. In 1961 Convair Aerospace in San Diego first applied COM technology commercially, and in 1966 the Lockheed Technical Information Center in Palo Alto, California, first applied COM in library-related applications. COM products (mostly on fiche) included parts catalogs, price lists, directories, banking data, and managerial reports. The small microfiche reader became ubiquitous in many chain business establishments, including banks. With the advent of machine-readable (computerized) cataloging standards in the mid-1960s, libraries adopted COM technology to produce their catalogs, outputting bibliographic information on roll film that was mounted in specialized readers. With computer-based system development the potential for further improvements of microfilm-based systems was diminished, but the existing microfilm industry found ways to continue its utility. The use of microfilm in these applications also serves as a reminder of how seldom an established technology or an entire information system is completely eclipsed by a new one.

Conclusion

Microfilm, like any information system, has its strengths and weaknesses. One strength is in its ability to preserve information for long periods of time and another is its ability to disseminate information cheaply. The persistence and ubiquity of its parent technology, photography, is an important factor in maintaining this low cost. However, digital photography portends major changes in the technologies used for information storage. Once digital photography penetrates fully into the mass market and new storage mechanisms are developed for digital information that strength may decline. And the World Wide Web offers amazing new facility for instant dissemination of up-to-date information, including the most sophisticated graphic images.

Microfilm's weakness lies in its limited retrieval and output capabilities, both in print and on screen. The repeated, unsuccessful attempts to design comfortable, convenient readers were a testimony to this lack. If today's sophisticated and inexpensive printing technologies had been in existence then, this limitation might have been overcome by converting from screen to paper as is often done today with electronic information. However, the challenge to provide higher levels of retrieval would not be met by even the most sophisticated printer. Microcards and aperture cards were two valiant and very different attempts to improve this aspect of microfilm technology and to provide standardization as well. Although these formats were far from the automated retrieval systems needed to search and rank data quickly and precisely, they did represent an evolution along the way to improved scientific information systems. What the accumulated history of microfilm-based information systems demonstrates is that scientists and engineers, scholars and librarians tried again and again to invent robust information systems because this is what they needed to do their work effectively.

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