Microcartography and Cartographic Data Bases

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IN MAP COLLECTIONS,* the past few years have seen a shifting of concentration from acquisitions matters to those of collection management. Acquisitions procedures are now fairly well fixed and results are in almost direct proportion to effort and money expended. In the past, great amounts of money and effort could not accomplish the same end; in most instances, maps were simply not available. Now, internationally, fallout from the large-scale, high-speed remote-sensing and map-making technological revolution is increasingly available, and concern for managing this ever-expanding information store has risen accordingly. The increased availability of products is placing particular pressure on manpower and storage resources, forcing administrators to explore alternatives to traditional management methods.

The most promising of these alternatives appear to be computers and microfilms, both separately and together. Separately, microfilm offers a better than 90 percent increase in map storage efficiency, with commensurate labor savings; computerization promises absolute information control and revolutionary capabilities in information restructuring. Together, microcartography (i.e., microfilm technology applied to the field of cartography) and computer processing offer capabilities greater than a mere sum of the parts.

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*In the current context, *map* includes aerial photographs, space platform remote sensing, Polynesian stick charts, physical relief models, and an ever-expanding panoply of materials in addition to traditional "maps"; map collections are where these artifacts are classified, housed, preserved, and utilized.

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The current trend objective is to rationalize this synergy using paper where necessary (because it is "humane" and preferable for many applications), microfilm (because it is small, cheap and versatile), and computers (because they are very fast). The result—depending on the degree of application—will gradually transform the traditional map collection from a static, passive repository to a cartographic assembly point (i.e., memory bank), the last or next-to-last link in the map production chain, and just one element in a more general geographic information system (GIS), itself mergeable with parallel collections from other information systems.

Present Constraints

Elsewhere in this issue of *Library Trends* will be found discussion of the rate of increase of map collections, in both number and size. Even the largest of these public collections—the Geography and Map Division of the Library of Congress, with about 3.6 million maps and an accession rate of nearly 60,000 maps in 1979[1]—does not pretend to be absolutely comprehensive; there is neither money nor manpower enough to collect all maps being published.[2] While LC G&M now has adequate space—about 93,000 square feet—the largest academic map collection (UCLA's, with close to 500,000 maps) has storage cabinets stacked ten feet high and split between two locations.[3] Yet another instance is the long-standing policy of the Detroit Public Library to retain only the most recent editions of domestic series maps in most instances.[4] While their circumstances are unique to each of them, LC G&M, UCLA and Detroit Public are typical of the limitations prevalent today: every library cartographic collection is on a trajectory to the same end, no matter how far away such curbs may appear at the moment. Thus, as important a trend as it is, the growth of map collections is being held back by secondary restraints. In the face of innovative products and user expectations which transcend traditional collection guidelines, and even within them, pressure continues to accumulate, causing displacement of maps and de facto guideline shrinkage, until a steady state becomes almost inevitable, in which any acquisition displaces something already held. And still maps become available at an increasing rate.

To improve information delivery within these financial and physical constraints, both map producers (led by the military/intelligence establishment) and map librarians (led by archivists and local governments) have turned to microfilm to reduce the costs and sizes of maps, increase storage efficiency and reduce unit labor.[5] Since the storage savings are so great, microforms would allow for virtually open-end collections, which eventually aggravates a further set of problems: how is a ninefold increase in collection size and accession rate managed within current manpower budgets? Computers are the obvious hope. It is little wonder, then, that those who can afford to are already exploiting this space/time savings to obtain the dual benefits of high-density storage and high-speed automatic retrieval.[6] In the future, the same will hold true for those who cannot afford to do otherwise.

Fortunately, in contending with the general onslaught of information, libraries have already begun acquiring those management technologies and forming those structural regroupings which provide the very capabilities needed to handle huge cartographic data bases with limited personnel, and the means for integrating them with other spatial information. Data bases are no longer limited to already digitized information, but include those information bases eminently digitizable, as is the case with maps; if transaction times are equal, the distinction between analog and digital data bases becomes moot.

Library Data Management

Library data management has taken a number of radially adaptive approaches, all of which can be distilled into three functional groupings: cataloging, bibliographic searching, and nonbibliographic data base management, all of them overlapping to some extent.

Cataloging

The on-line cataloging data base and its variants, internal creations or parts of cooperative networks, ubiquitously tie together all types of libraries and all levels of personnel, either directly through networks or indirectly through similarity of experience. It is, or probably will be, the point of introduction for map librarians to computerized data bases, representing the basic management tool necessary for identification and control of the very large cartographic collections now accruing. At the center of these developments, internationally, is LC's MARC-Map cataloging system, used to catalog individual maps and entire series. Supplementing it in the United States is the U.S. Geological Survey's Map and Chart Information System (MCIS), used to analyze maps within series (or sets); microfilms of these maps are made available through the National Cartographic Information Center (NCIC). Assuming current efforts to mesh MARC-Map and MCIS are successful—and there is no reason to assume they will not be—the domestic on-line map citations will expand significantly, providing impetus to collect the cited material when searching the data base, and the capability of managing it once acquired. (It will be as easy to acquire a reel of 500+ maps in microform, and only slightly more expensive, than ordering a single cited sheet on paper: $10.) When mature, this data base will include geographic coordinate search subroutines for actual map reference work, where area searches are more productive than citation searches in most cases, although author, title, format, or subject delimiters will be available, too. Coordinate searches—equivalent in many ways to relational searches of books—will be provided by one of the on-line cataloging service bureaus, such as the Research Libraries Information Network (RLIN), the OCLC, Inc., MCIC (which is programmed around this capability), or some complex, local routine.[7] Presently under investigation are the protocols necessary to add digital data bases and computer programs to this cataloging data base as well.

MARC-Map/MCIS also represents a fundamental tie between standard library cataloging and the national mapping agency, an essential link in progressing to some of the other cooperative possibilities considered below. It is hoped that this will be followed by equivalent cataloging records from other countries as their national map agencies apply computerized information management technologies to their burgeoning output.

The second class of data base and access includes the approximately 450 bibliographic data bases available on-line through more than sixty proprietary services.[8] These services are tapped by libraries through dedicated communications networks and can, increasingly, respond with full text—either on-line or by mail—in addition to their normal abstracting capabilities. These data bases already include a great deal of cartographic or cartography-related material, including research and development, geography, history, education, geology, and maps in periodicals.

Unfortunately for patrons, the skills needed for effective searching come only with practice and are improved only through continual application; and libraries are only gradually committing personnel to such work, usually starting with general reference librarians. These skills are, therefore, dependent on volume and technology—not subject. For the same reasons, strictly cartographic data bases such as MCIS may not be picked up by the commercial services for some time, and when they are it will probably be general reference librarians with data base search skills, rather than map librarians, who will utilize them. This is true except for the largest and busiest map collections, such as the University of California at Santa Barbara's Map and Imagery Collection, which is already on-line with MCIS.[9] Since it is now necessary to establish a separate billing account for such service, it will probably be some time before market resistance overcomes the inconvenience; lining up behind MCIS are a number of other U.S. Geological Survey data bases of special utility.[10]

Digital Data Bases

The third type of computer-dependent library data management is that of the nonbibliographic data base manager/librarian, whose duties include ordering, storing, assessing, converting, and maintaining actual data tapes, their documentation and supporting literature collections, as well as arranging for the use of such tapes with central processing unit (CPU) personnel.[11]

Just as large research libraries are fragmented along disciplinary lines, so too, usually, are these library and library-like extensions. Thus, while a social science data base manager will probably be conversant with demographic data, the same manager may well have little idea of developments in the earth or engineering sciences, a circumstance reciprocally honored by counterparts in those fields. Unfortunately (in some respects) for map librarians, pure cartographic data bases—those not integral with some other information base—may tend to fall between such disciplinary alignments, being in no one's exclusive domain.[12]

Naturally, data base managers also tend to cooperate along disciplinary lines, pooling their resources in such associations as the Inter-University Consortium for Political and Social Research,[13] which acts as a national clearinghouse for social science data tapes and such program packages as the Statistical Package for the Social Sciences; and the International Association for Social Science Service and Technology (IASSIST), which sponsors various action groups concerned with the "nuts and bolts" issues of data base management. At least tangentially, these concerns include interest in such activities as the International Federation of Data Organizations' "Symposium on Joint Data Bases for Regional Analysis and Computer Cartography," one of whose aims is the creation of a catalog of European cartographic data bases.[14]

Institutionally, social science data base librarians show some other signs of commonality with map librarians: UCLA's Institute for Social Science Research is well represented with geographers, and the map collection at San Diego State University was integral with SDSU's Social Science Research Laboratory for a number of years.[15] The institute and the laboratory are typical in that they are cross-disciplinary, fully computer-capable—verging on computer-dependent—research alignments centered on a technology rather than a strict field of study. It remains to be seen whether such nonbibliographic data base groups will access "pure" topographic, geodetic, geologic, and remote-sensing information such as is generated by cartographers and earth scientists. Indicative of the current state of flux is the fact that SDSU's map collection recently returned to the general library as a subunit of the documents department.[16]

Ultimately, some of the technical developments discussed later may tend to supersede the need for specialized digital data base departments of this first-generation type. But such evolution is at least partly dependent on a number of extrinsic factors, including library capability, data base availability, and its format suitability to map collections, any of which can accelerate or retard implementation.

Capability: Libraries and Data Bases

In spite (or because?) of what they have already accomplished, libraries are still confronting some very general issues regarding digitized data bases. If no provision is made for absorbing these data bases internally, libraries may be sidestepped as handlers of such information, a contingency being actively investigated. This assessment is based perhaps on sketchy extrapolation of promised communications breakthroughs, which have led some to the conclusion that unless libraries participate fully and immediately in the computer revolution, they will atrophy as information centers.[17] Such logic overlooks the organic relationship of libraries to the culture which created them, overlooks what has already transpired, and is oblivious to the perspicacity of the library community. From the library point of view, it is essentially a matter of when and how, not whether, to set up an internal or dedicated external processing system, and of how earnestly to pursue a central information delivery role in the light of general priorities.

Sophisticated processing units are shrinking in both size and cost, as their capabilities increase to the point that for many applications, it is becoming more expedient to purchase rather than connect with a remote unit. (If a $20-per-hour-programmer spends one hour per day commuting to a remote processor, it will not be long before a small processor can be paid for with the savings of keeping him/her within the library.) However, there remains some question as to the cost/benefit of such services (not equipment) when contrasted with present general patron needs, although the cost and benefit lines will no doubt cross soon and the equipment/service will be implemented gradually.

The alternative would be to stand idly by as federal, state and local agencies—the principal sources of data—or factional academic departments install their own data bases in regional, state, local, or academic service outlets with on-line capabilities. These same government agencies would continue to supply libraries with the traditional off-line printed equivalents, which are often inferior in content, not to mention more difficult to use.

A typical case in point is the U.S. Census Bureau, whose Geographic Base File/Dual Independent Map Encoding (GBF/DIME) files are used heavily by digital data base organizations of every persuasion and have multiple applicability in map libraries. Each decade the GBF/DIME-population census—only one of a number of topical censuses, and itself now scheduled to appear every five years—becomes more grandiose. Current estimates place its printed version for 1980 at roughly 300,000 pages; the microform version on 40,000 fiche (containing 30,000 maps) will be greater in content but still fourteen times more compact. However, neither will contain all of the statistics available on the digital tapes.[18] These tapes will be available at regional or state data centers, and at least some of them will be picked up by academic social science data base libraries, such as those at UCLA and San Diego State University. But how long will it be possible for the Census Bureau to supply 300,000 printed pages every five or ten years to each library requesting them, and for how long will libraries find even the microform version tenable when (and if) the digitized version becomes easier to use?

It may well be that 1980 represents a significant transitional date: it marks the beginning of the "Worldwide Census Programs."[19] By 1985 or 1990, full printed censuses may be a rarity—unless everyone simply balks at the prospect of another census entirely—and the microform version may be at the end of its tether unless it is constructed and delivered with an integral semiautomatic or automatic information retrieval unit.

Map librarians will certainly have to think twice about accessing relevant parts of the microform version if they are seriously interested in the map content, or somehow manage to utilize the digital version. As to their inherent utility, census-produced maps such as the metropolitan map series of the 1970 census—pocketed in many census reports—have proven a boon for the past ten years and are looked forward to as at least a decennial update of accurate street maps of many U.S. cities.[20]

Another example of regional and state data outlets familiar to map librarians involves NCIC's plan to establish state-sponsored cooperative centers for cartographic information, perhaps with the tacit assumption that the state would act as an intermediate node to libraries. Currently, this plan is operational to some degree in twenty-three states, the same number of affiliates as in the Census Bureau's program.[21]

NCIC, which is responsible for distribution of the Geological Survey's information systems (including its digitized map files) is now approaching libraries experimentally as formal partners, to provide its computer output microform (COM) equivalents of MCIS, APSRS (Aerial Photography Summary Record System), and forthcoming graphic microindexes to remote sensing.[22] If successful during its test phase at Seattle Public Library, this cooperative distribution program could evolve into one of the first nonbibliographic data bases networked directly to libraries by a federal agency, in which the library—which provides personnel and expertise—is utilized as an active partner and quasi-official representative of the agency itself, making explicit what has been implicit in patron's eyes all along.

The evolution of these relationships will depend heavily on library administrative willingness to budget the personnel and equipment (mainly microform readers and reader/printers at present), the evolution of hardware, and the successful "marketing" of library capabilities to public agencies and the user public. Its future growth will also depend on the willingness of data base generators to increase the utility of and public exposure to information programs whose costs are already being carried, as NCIC is trying to do.

Since the ultimate role of the federal government is not clearly established, it seems probable that depth of information supply will somehow be tied to library use patterns and capabilities; in other words, it will likely be volume- and technology-dependent. This will favor large city and research libraries, which are already staffed with the internal expertise (including computer programmers and technicians) to provide the very support needed for data distribution, and which also have the specialized staff already familiar with the data base content—a fact overlooked by some in their assessments of state and local processing capabilities.[23]

If the trend of agencies such as the Geological Survey should mature in libraries, not only would users benefit directly from a multiplicity of data centers, but a critical momentum could develop which would tend to attract other federal agencies, many of whose data bases are areal in nature; state and local agencies can be expected to follow suit, provided they have not already anticipated this advantage. It seems obvious that cooperative placement of these data bases in libraries would be a service to all: the agencies are spared a number of heavy overhead expenses; libraries retain their traditional function of information distribution; and users gain access to additional resources at the traditional place. But its obviousness will not necessarily insure its adoption; for that, we are at least partly dependent on the actions of legislative intermediaries.

Many of these and related information distribution issues were topics of concern at the 1979 White House Conference on Libraries and Information Services; the consensus resolutions were then forwarded to the president of the United States.[24] These same issues are also of continuing concern to the National Commission on Libraries and Information Science (NCLIS), which was established by Congress to study the overall problems of libraries and information distribution.[25] Finally, Congress's own Joint Committee on Printing, which has revised the "Depository Distribution Act,"* was on a parallel course.[26]

Depending on numerous imponderables, the White House conference resolutions, the NCLIS recommendations and the committee's decisions will have fundamental impacts on the financial and technical problems of data distribution, but perhaps more significantly, they may collectively reassert as national policy the function of libraries in their traditional role as conduits for public domain information, possibly going so far as to supply the hardware necessary to make even the microform and digital information intelligible.[27]

Availability: Federal, State and Local Data Base Development

Like other local, state and federal agencies converting to digital data bases, the U.S. Geological Survey retains three media types of data base products: the traditional paper version, an equivalent microform version (as well as COM indexes), and refined digitized data; for USGS, the last category includes such "pure" cartography as terrain profiles and digitized color/feature separations of map content.[28] In regard to digitized data, USGS has initiated development of a national cartographic data bank comprising at least eleven discrete map elements, all (except such cultural factors as names and boundaries) encoded or encodable directly from aerial photographs. These data can then be analyzed separately or collectively, or combined with other spatially

*Title 44, U.S. Code. The bulk of USGS maps are distributed under Title 43, Section 42, which is also in need of revision.

dependent information to generate either maps or data tables. This will be the core of earth-related information at the national level, and has the dual advantages of centrality and uniformity—real problems with all data bases, but especially severe with cartography, which is currently in transition from point/line/area encoding to raster ("pixel") encoding.[29] Supplementing this data base, which is still in its initial stages, will be more detailed surveys by state and local governments. Many of these surveys are in the formative stages, and some are already operational.[30] Potentially, other supplements will be combinable with these core data to yield a myriad of graphic, areal intelligence.

In regard to cartography, there is no comprehensive index, directory or catalog of these developments, so potential users must depend on irregular books, symposia and articles, or must resort to tribal communication networks to keep informed—such is life in the global village![31] However, the recent emergence of a dedicated literature forum, including the *Harvard Newsletter on Computer Graphics* and *Geo-Processing* (both appearing first in 1979), to supplement the traditional sources is indicative of the emergence of computer-assisted cartography as an independent field and should aid greatly in resolving the problem of keeping current. Since surveys are already underway at the international level, and provision has been made to add data bases to the MARC catalog, a good, universal directory could be available shortly. In the meantime, it is safe to assume that all industrialized countries are presently developing such digitized cartographic data bases—implementing them piecemeal in slightly varying ways and at varying rates—and that nonindustrialized countries are actively considering them, but confront both economic and cultural obstacles, obstacles from which no one is immune.[32]

Suitability: Map Libraries as Mass Memories

Implementing the traditional functions of the map library using conventional digital information may be difficult because of the sheer magnitude of the task: to a computer, the basic difference between a linear stream of words or statistics and the graphic content of a map or air photo is the density of information involved. Size for size, a topographic map on paper requires about 10,000 times the data storage needed for text. This printed page, for instance, requires less than 34,560 data bits; an equivalent air photo is on the order of 100 million bits,* as

*These are maps and air photos which have had their information compressed; in raw form, the figure can exceed 1 billion bits per image/map.

is a standard quadrangle map.[33] The United States alone requires about 63,000 such maps for complete coverage, each quadrangle preempting two reels of data tape.[34] Held in this fashion, the map collection of the Library of Congress would consist of 7 million reels of tape and would grow by about 120,000 reels per year. With all of the attendant service requirements, including periodic "refreshing" of the data, replacement of the tapes as they age, lengthy setup time, unpredictable hardware problems, and in short, a general lack of suitability in a map library environment (where demand for any given map is measured on a less than yearly basis), such an arrangement is clearly impractical. Such a store also assumes that the maps are available free on tape (the current cost for a federally produced data tape is $80); it would be prohibitively expensive for a map library to add wholesale digital conversion to the current work load: "Thus far the experience of the National Archives is that it costs approximately $360 in staff time, computer time, and supplies to accession a single reel of tape and prepare it for dissemination when it is software independent, is in a standard code, and requires no data compactation....[And,] the long-term preservation costs using existing storage technology over the next twenty-five years would be about $5 per year for each reel of tape."[35] Given this dismal prospect, it is fortunate for map librarians that alternatives are available.

Videodiscs

One proposal for mass storage which transcends the weaknesses of digital tape is the videodisc. Each disc can hold up to 54,000 color images, including air photos or maps; they are relatively inexpensive to emboss ($5 to $25 each); they have archival attributes (if laser-compatible); they are integrable with computers; their images can be accessed randomly; and blank discs, produced in quantity for both the audio and video industries, will make hardware plentiful and cheap.[36] Because they have so many attributes, such discs are bound to find applications in libraries generally (perhaps replacing microfilm in many cases, such as serials), but they do have limitations which make them problematical for map collections. Making the initial recording and just a few copies* is expensive because it requires special equipment and a special environment; information cannot be updated or interfiled on the same disc once it has been "mastered" and distributed; and finally, the technology is inherently hardware-dependent. Thus, imple-

*It could well be that demand for maps in this format could mushroom beyond all reason if they somehow appealed to all libraries and to home users.[37]

mentation and use will have to be on an all-or-nothing basis, a bridge to be crossed wholesale—with some trepidation.

Still, even with these limitations, there are certain cartographic applications which could be ideally served, especially those projects impossible now because of their sheer magnitude. For instance, discs would be a great way to distribute large sets of remotely sensed images, including complete national, state, county, and city coverage in ascending detail on a cyclical basis (in effect, an aerial census). The main limitation now is the price of the photographic medium, not the data. Thus, where 54,000 nine-by-nine inch photographic transparencies now cost from $150,000 to $1,350,000, are difficult to sort, and are expensive to store properly, videodiscs would make it possible to supply the same imagery for a fraction of the cost, especially if initial recording were underwritten as a necessary overhead expense by the agencies concerned.[38]

Since the medium is permanent, it is of obvious interest to archivists, who, given their need for a master disc, could underwrite their recording expenses by selling pressings to map libraries. Canada's National Map Collection—always a leader in applying technology to information storage—is already at work testing the feasibility of recording its map holdings this way; their results may well change the rules by which the map library game is played.[39]

Consider then the resultant possibility: 2 discs per 100,000 maps/air photos; 20 discs per 1 million; 200 discs per 1 billion.... It seems doubtful that a billion cartographic items have been produced worldwide up to now, but the capability of doing so, on an annual basis, is not far off, especially if the information can be rapidly and inexpensively recorded outside traditional photographic technologies, perhaps through real-time recording on a temporary, recyclable holographic medium and then off-line batch-recorded on videodiscs.[40]

In addition to their other persuasive merits, the fact that videodiscs are integral with a cathode ray tube (CRT) may mean as much as anything else in the long run. First, this package of memory and display comprises two essential ingredients of a digital cartographic system. Second, this combination will be useful to the library in other ways, making the components attractive to administration. Third, the playback unit can be attached to any television receiver. Fourth, the CRT can be used for receiving remote transmissions—these transmissions can always be videotaped. Fifth, there are simple CRTs, such as those used at home, and there are laboratory models with integral software capable of virtually all the computer-assisted cartography tricks, including: high-density scans—there is an obvious advantage to closely spaced lines if the picture is to be enlarged significantly; manipulation of each picture element or "pixel" (a function of beam size multiplied by the number of scan lines); color and density manipulation in 1056 steps; interactive user addition or deletion of information; accumulation of multiple, registered images; and, as if that were not enough, special cameras have been developed to intercept the image and create undistorted prints or transparencies.[41]

A greedy, ideal scenario for map librarians would have such disc collections completely sealed and self-service, using the equivalent of a jukebox (with the system at rest displaying a map of the world surrounded by alphabetical rows and numerical columns), or perhaps using a "joy stick" to control a location light. By pushing appropriate scale-change buttons, the image area would expand to fill the screen with a more (or less) detailed map and/or air photo; this process could be repeated to enlarge any portion of the earth to the desired size on the screen. Assume that the jukebox would hold 200 such discs, and further, that logic and memory chips could be added to expand the unit's capacities incrementally—for instance, a television camera could input images of paper maps, microforms or the like; the scene could be synthesized or rotated; elements could be emphasized (by color or intensity)—and you have some idea of what is technically feasible now, and implementable over the next twenty years. In fact, viewed from the unaccomplished side of such an endeavor, the main delaying factor in this scenario is the time required to overcome present organizational inertia (which exists for some worthwhile reasons).

Microfilm

The second alternative to digital tape storage is microfilm. As useful as videodiscs portend to be as visual and mass-memory devices, microfilm offers even more current capability. Its litany of attributes includes the facts that it is inexpensive in large or small volume; it can be generated by almost anyone, anytime, under almost any circumstances; it is part of an evolving technology; it is inherently graphic in nature but is equally useful for digital storage; it can be updated, interfiled, erased, automatically retrieved, random-filed; it can be viewed, enhanced and manipulated on the same CRTs used for videodiscs, as well as a multitude of other viewing devices; it is portable and permanent (or permanent enough); it has been around for more than a century—and has been of interest to cartographers the entire time.[42] It also has a certain practical momentum of development and use which may continue for the foreseeable future to make it the storage medium most appropriate to the map library, and libraries generally, because it is the broadest-based, least common denominator for all applications, is already used extensively, and requires minimal cultural adjustments. It also shows great potential for symbiotic development with electronic technologies such as electron beam recorders (EBRs), lasers, solid-state optical arrays, and computer integration in a context where maps are simply another type of information using a universal medium.[43]

Although certain fundamental issues regarding the format of cartographic microforms are still debated, there is little doubt that they should conform to standard industry practice where possible, using the international 105x149mm microfiche as the base filing unit.[44] Film production considerations will favor adherence to this standard, even though the carrying capacity of film per unit area may increase dramatically. In the future, the additional space gained can be used either for innovative information packing, or for different optical approaches to using the content.[45]

The sum of possible results is clear: many more maps produceable, in greater detail, at a fraction of current paper map costs; allowance for superimposition of multiple images on the same film base; the sandwiching of several very thin films—in register—to build up maps on a custom basis; and the synthetic generation of color information from essentially black-and-white transparencies—using colored diazo films, zero-order diffraction (ZOD) microforms, color filters, synthetic color (based on gray-tone spectromatic signatures); or straightforward, long-life color transparencies.[46] Yet, actual implementation remains tenuous, largely because sophistication of high-volume viewing equipment has lagged so far behind that of recording instruments: library demand for first-rate readers and reader/printers has been misanthropically absent, so they are not manufactured in quantity and their prices remain absurdly high (basically, only a light source, a lens, and a carriage to hold them are necessary). EBRs, for instance, are capable of addressing 1 billion points on a microfiche (the data bits required for storing an air photograph or map), and are used right now for computer-generated mapping,[47] but microform readers capable of exploiting this imaging density *start* at $10,000 because the market for them is so limited. (A third generation of reader equipment is on the horizon, however, characterized by solid-state electronics.[48])

Read/write lasers expand all capabilities even further: they are not limited by vacuum-tube technology as are EBRs and CRTs, and like videodiscs, they both record and extract color information.[49] They, too, are computer-compatible and high-resolution, but also can produce incoherent or coherent (holographic) light-readable microforms,[50] or pack multiple images on the same area of film, potentially raising packing densities by a factor of eight (no mean accomplishment, when millions of cartographic microforms are being considered). And, they operate in the micro- to milli-amperage range, which makes them magnitudes more energy-efficient than conventional microfilm equipment.[51] These lasers have the additional advantage of having a very wide critical focus, which allows them to read a stack of registered microforms simultaneously (before a map is printed, it exists as a series of color or feature separations); and they can read or project at long distances with equal facility, making it feasible for them to go to the microform and retrieve the information while leaving the microform itself in place.[52]

NASA, the U.S. Air Force, U.S. Army, and U.S. Navy are all presently exploring this technology to create cartographic mass memories—in effect, map libraries—roughly equivalent in size to the map collection of the Library of Congress, all to be available on-line or in near real-time storage, and housed in as little as 1000 square feet (versus, for example, LC GMD's 93,000 square feet).[53] While the maps in these systems are digitally encoded on film—partly out of habit, partly to increase their fidelity, and partly to reduce their size maximally—there is no technical reason that the maps could not remain in the graphic state other than that it might require slightly more response time and slightly more space. Given the scaler reductions already possible with conventional graphic microforms, the cataloging platform being constructed for them, the advantage of gradually working up to such sophistication, the more relaxed time demands of a library environment, and the intrinsic graphic capabilities retained, the trade-off of graphic for digital seems definitely to favor the graphic format.[54] Also, while the digital mass memory is absolutely hardware-dependent, graphic memories are not, and they have already proved themselves in cartographic computer-input microfilm (CIM) applications which include textual information in the same system.[55]

Implicit in these developments are size, sophistication, and compatability with mixed-media data bases—incentives of major proportions.[56] But from the standpoint of all libraries, the most compelling incentive by far is the fact that as state-of-the-art map libraries gain enormous content, they shrink in size, making quantum jumps in utility with the addition of each piece of multi-use hardware, all of it capable of translating freely from analog to digital and back again.

Patrons using such collections will probably like their rapid response time best—virtually instantaneous compared to paper map collections; and a future which promises to provide us with computer-/micro-/paper-compatible color photocopies cannot be all bad.[57] While the end product—a colored map on paper—may still be the object of preference, such maps need not be arbitrary, either in terms of content or area displayed. (While the four-*color* map problem has amused mathematicians for years, the four-*corner* map problem has an equally honorable history among map librarians; as J.B. Post of the Free Library of Philadelphia expressed it, "Why do important battles always occur where the corners of four sheets meet?"[58]) Given appropriate hardware, a completely tailored map can be generated on the spot, drawing from a very large store of microform map color/feature separations, registered satellite images (for large areas) or aerial photographs (for small areas).[59] Given such capabilities, off-line microform storage may well provide the optimum solution to current problems of space and labor.[60]

Financing such developments will require a complete rethinking of the current ratio of expenditures for collection development and the equipment to exploit its content, perhaps best effected through budgetary incentives. That is also why the actions of government data base suppliers, the White House Conference on Libraries and Information Services, the Joint Committee on Printing, the National Commission on Libraries and Information Science, and local library administrations are so important: in concert, they can realign and finance the needed priorities. But finally, it is up to map librarians to convince first themselves and then library administrations that they need to trade floor space for hardware. For instance, a moderate collection of about 100,000 maps is currently allowed about 5000 square feet, which represents roughly $500,000 worth of building space.[61] If this can be reduced by half, there is in effect a $250,000 capital gain in equivalent value to be bargained with. The difficulty is to translate this capital gain into a liquid asset, freeing the money for reapplication where it is needed most: the equipment which will save the space and provide superior service within current manpower budgets. (These can be kept level through resulting increased productivity.) In an earlier paper, the author attempted to show that the microform information base needed to bring about such an accomplishment is already available or could be generated readily.[62]

Sources

While the sources for cartographic and other data bases will remain the same, the agencies supplying them will be in a position to respond with appropriate formats—paper, microform or digital—because they, too, are already or soon will be using the same multiple technologies for internal purposes, and will in a sense simply be relaxing the artificial barriers which now separate them from libraries. Where such data stores are purely digital, at least for maps, they can be generated graphically on COM fiche.[63]

Orchestrating these data bases within and across governments continually becomes more fluid, but each level of government has a finite jurisdiction; only a few intelligence and military agencies will ever have the overall international needs or responsibilities for data acquisition to be found in the most rudimentary map library. Thus, it is the responsibility of map librarians, and it is in their self-interest, to implement or support appropriate technical developments at the international level, just as they have so successfully done with map cataloging. This is usually best effected by purchase decisions based on long-term needs, not just current availability. It is also dependent on a broader point of view than just the immediate collection; it encompasses all map collections everywhere. Thus, rather than just considering a map a map, if it is considered a portion of a growing mass memory for subsequent use in a library which has, or will have, the vast majority of its holdings on microfilm and (probably) videodiscs, then the format of the map becomes an important issue, divorced completely from the issue of its content; the content is, at worst simply maintained, but if its utility can be enhanced, to that degree it is a more valuable resource.

Programs

Completely separate from the mass-memory considerations of information storage are those of information manipulation. Sophisticated computer programs are already available in solid-state devices, and such built-ins are growing at a phenomenal rate. There is no reason that "smart" typewriters and video terminals with their own memories will not be followed by "intelligent" cars and "smart" microfilm readers (already available with index sensors). To be anticipated are automatic density control—contrast is the most important visual factor in readers—and readers able to manipulate an image before projecting it onto a (perhaps remote) screen. But for the present, it will be programs such as the Jet Propulsion Laboratory's LUMIS (Land Use Management Information System)—capable of handling mixed-source inputs—which will fulfill the most needs.[64] Unfortunately, there is no comprehensive directory to all such programs—many outside the cartographic field are relevant and useful—so conversance with the standard sources will become necessary, starting with directories of the host central processing unit and moving through the various government and commercial directories now in print. These include NASA's COSMIC (Computer Software Management and Information Center) catalog; the National Technical Information Service's (NTIS) *Directory of Computerized Data Files, Software & Related Technical Reports*; the Geological Survey's growing list of software, available through NCIC; the Department of Transportation's comprehensive (but somewhat outdated) *National Geocoding Systems*, which includes a number of private sector programs; the Department of Commerce's *Federal Software Exchange Catalog*; the Census Bureau catalog; and commercially available programs from specialist computer laboratories, such as the Harvard Laboratory for Computer Graphics.[65] In short, there must be countless programs available, many arranged in hierarchical management routines.[66] However, what will be needed by map librarians—based on the experience of data base librarians—is something akin to the Statistical Package for the Social Sciences, that is, a core set of standard algorithms which serve the integrative information needs of the general library on the one hand and the specific needs of the map library on the other.[67] Such a package will have certain predictable attributes: common program language, provision for reassembly of data into a useful structure, browse capability, and a very simple, interactive personality.[68] Such an overall library management program is frequently discussed in computer, information science, and library literature, but to my knowledge has not yet surfaced in practice, although many of the building blocks are already in place.

In the meantime, it is far more productive to concentrate on satisfying the minimum machine and human requirements, working up a body of expertise which will satisfy the requirements of both current and future users. Eventually, the programs—as well as the digital data bases—will be cataloged into the MARC on-line data base, will probably be available as plug-in modules,[69] and will present no more difficulty than is inherent in video games.

Computers and Map Librarians

Once a map collection passes the 100,000-sheet mark—and we are considering near-term collections orders of magnitude larger—some, but not necessarily all, aspects of information management can be better handled by computers, which do not get tired (although their breakdowns are notorious), seldom forget, and only have to be trained once per hardware generation (typically eight to ten years). But there are intermediate structural information arrangements not requiring computers, especially those which take advantage of the locational peculiarities of geographic information.[70] As the librarians at Princeton University discovered, computers may not be as appropriate as manual or hybrid approaches in all cases;[71] perhaps it is just another instance of having to crawl before you can walk, but hybrid computer/microform approaches seem to offer the best return at present.[72]

In regard to actual information use, on-line computers again have not proven themselves more versatile than many manual or hybrid COM approaches to information restructuring, manipulation and use, especially when cost/benefit is considered. There is still plenty of room for the ingenious to improve on current optical capabilities—in fact, although they have been something of a silent partner over the past decade, current optical processes can do most of the things computerized picture processing can do, and in most cases more easily, more quietly and more reliably.[73] Computer intervention has a great deal further to come toward the user before it displaces or supersedes optical-mechanical manipulation in map libraries. In fact, a very good Homeric argument could be made for not adopting the change to computers at all, but there is no way around the fact that only computers can make the digital-to-analog conversion, and only they exhibit the requisite speed necessary for assembling and synthesizing large volumes of disparate material or laborious calculations into a useful amalgam.[74] Optical process cannot, for instance, transform data tables into their graphic equivalents, as does the government's Domestic Information Display System (DIDS).[75]

The Future Role of Map Librarians

Translating all of the "can do" technologies into "will do" map collections is the predictable challenge and opportunity with which the profession will occupy itself in the foreseeable future. Trying to exploit systematically all of the seemingly incoherent practices, politics, concerns, and capabilities now before us, and doing it on an evolving foundation, will be the functional fate of all librarians. As the spectrum of (map) producer and (map) user sophistication continues to broaden, (map) librarians will be forced to expend more attention on information theory, on technical delivery, and on human factors influencing aspects of cartography and information science. As the nexus of many prevailing forces, they will have to act as intermediaries, advocates and reality contacts for the multivariate clientele to be served, whose needs still range from the unilateral requirement for good street maps, through sophisticated planning analyses, to such exotica as trans-topographical comparisons of reality with completely synthetic worlds.[76]

Serving this clientele will transgress many of the traditional barriers separating discipline-related library groupings, as map librarians share technological commonality with other information specialists. This will mean sometimes turning over functional responsibility for cartographic research, sometimes applying completely noncartographic expertise to answering patently cartographic questions (as in the comparative aspects of Brownian motion factual studies and the real world, or the impingement of catastrophe theory on areal dynamics).[77] Maps then become only another discrete ingredient in the information soup, not an end in themselves. Thus, map librarians will tend to become integral and integrating specialists within libraries, gradually arming themselves with capabilities to deliver need-specific information built up from lesser components rather than to provide random, partial or encyclopedic catchalls from which relevance must be extracted. Such work may involve the integration of partial informations from a number of maps of different scales and eras, from different agencies designed for different purposes, coalescing them into a unique product which may never need to be reassembled in that particular way again, but whose components will be free for rearrangement into a multitude of other combinations at any time. To accomplish this, map librarians must move one step closer to cartographers, intercepting maps at the prelithographed separation stage (preferably in microform or COM), and one step closer to the user, offering a unique and relevant map, on paper (if needed), and in color. This prospect places us in a position to begin considering the assembly of holistic, synthetic historical environments, projectable into the future and using the present as a reality test, where map librarians provide the physical environment information and other specialists people it.[78]

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