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Mapping Technology in Transition

This presentation is a light-hearted mildly self-critical recapitulation of a 1985 book-length essay on the evolution and future of cartographic technology, which emphasizes the significant role of public policy in the collection, dissemination, display, and use of geographic information.

INTRODUCTION

However self-serving this talk might appear, it should be rewardingly informative—or at least informatively entertaining. The subject of my talk is a book—a book most publishers would consider a commercial failure. In the decade since its publication in 1985, *Technological Transition in Cartography* has sold fewer than 1,200 copies in addition to the roughly 200 copies the publisher seems to have given away. Even so, the University of Wisconsin Press still offers the book on its backlist, a service few trade publishers would dare provide.

Truth be told, Wisconsin was not my first choice for a publisher. I had offered the book to the University of Chicago Press, which turned it down after the first reader objected strongly to what she interpreted (quite incorrectly) as my promilitary viewpoint. My sin, it seems, was an unscholarly fascination with cruise missiles, those low-flying pilotless planes guided to their targets by digital maps, terrain scanners, and global positioning systems. Even now I find this technology not only fascinating but—if a war is unavoidable and the technology works like it should—infinitely preferable to napalm, carpet bombing, and a nuclear holocaust. University press boards react negatively to such criticism, though, and I agreed with Chicago's acquisitions editor that I should try elsewhere (ironically, my long-standing relationship with Chicago began several years later, when I approached the press with the manuscript for *Maps with the News* (Monmonier, 1989), which the Johns Hopkins Press had rejected after an even more vitriolic first reader objected that my way was not his way). Fortunately, my good friend David Woodward introduced me to the director of the University of Wisconsin Press. A pair of more open-minded readers agreed I had something worth saying, and the rest is cartographic history.

Technological Transition in Cartography was not only a fun book to write but a convenient way to reach cartography students, too many of whom seemed very narrowly focused on the technology of drawing maps with pen and ink, scribing tools, or pen plotters—manual skills with a very short half-life. I wanted to promote a broader view of mapping as a field in which technology was evolving rapidly and in which the principal product was geographic information, not the printable image. And I wanted to show them that dramatic changes readily apparent in the early 1980s would prove as deep seated and far-reaching as such earlier cartographic revolutions as printing and aerial photogrammetry.

ORGANIZATION AND CONTENT

The book was divided into seven chapters: an introduction, a summary and conclusions, and individual essays on location and navigation, boundaries and surveys, aerial reconnaissance and land-cover mapping, decision support systems, and map publishing and the digital map. In the introduction, a historical comparison of map copyrights afforded a brief examination of change in the nature of map products, which I related as well to the mapmaker's ability to adapt a wide variety of innovations, institutional as well as technological. The final chapter speculated on various ways mapping seemed likely to change as a result of the ongoing revolution, which I called the "electronic transition."

Although concrete examples were important, my approach was far more nomothetic than idiographic. Each chapter examined a variety of technological changes and speculated on the impact of recent innovations. Chapter two, which examined advances in location and navigation, attempted to place the cruise missile and global positioning system in perspective with a concise examination of earlier navigation aids, such as the Marshall Island stick charts, the Mercator projection, the chronometer, and sonar. The key conclusion in the chapter, though, was the effect on civilian mapping and navigation of "trickle down" from military and space. In no way an endorsement of the ''trickle down'' claimed by Reagan appointees advocating supply-side economics and massive tax cuts, my points were that "the perceived need for ever better national security will remain the principal impetus for major new developments in mapping and map use. [After all,] a good defense system requires accurate geographic intelligence and accurate navigation. Only the comparatively lavish appropriations for defense are likely to sustain the current rate of development in digital cartography. Mapping thrives on war and threats of war" (Monmonier, 1985, p. 45). The implications of all of this for the general public seemed clear: "Before [the year] 2000, [the map user] might well push a button on a small, portable pocket navigator and read out his coordinates accurate to several decimal places'' (p. 45). Although I had little to say about automatic vehicle navigation systems like the Etak Navigator, it seemed clear that: "Knowing where you are and how to get to where you want to go will no longer be challenging problems" (p. 45).

Chapter three, on boundaries and surveys, looked at advances in geodesy and land survey. Early illustrations describing the plane table, leveling rod, and surveyor's transit led to discussions of electronic distance measurement, triangulation networks, aerotriangulation, stereophotogrammetry, orthophotomapping, and inertial positioning systems. My concluding comment, though, identified similarities between geodetic control systems and the highway network: "Both facilities are geographically extensive; both require careful coordination and continual maintenance. Because direct user charges are troublesome as well as costly to assess, both networks are public-sector obligations, supported largely from general [tax] revenues" (Monmonier, 1985, p. 74). I drew other parallels as well, including recognition that even though a "surveying and mapping lobby" consisting of users, contractors, and equipment manufacturers is smaller and less powerful than the highway lobby, "both mapping and road building are influenced at least as much by political considerations as by progress in science and engineering" (p. 75).

The fourth chapter, titled Aerial Reconnaissance and Land Cover Inventories, also addressed topographic mapping, perhaps the biggest beneficiary of advances in aerial survey. I began by looking at the county atlases sold by subscription from the 1820s onward—the comparatively crude private-sector forerunner of the public-sector topographic map series. The U.S. Geological Survey, founded in 1879, initiated a topographic survey in 1882 with 15-minute quadrangles mapped at a scale of 1:62,500 and 30-minute quadrangles mapped at 1:125,000. A case study of Pennsylvania noted that state support of federal mapping, called "cooperation," had an important leveraging effect: the Commonwealth was mapped much more rapidly than the nation as a whole because the Geological Survey was responsive to states that contributed to USGS mapping activities within their borders. Ironically, when the Geological Survey appraised the quality of its surveys in 1946, the most recently mapped sections of the Commonwealth—the relatively remote counties of the "Northern Tier"—had the more accurate, more up-to-date maps. Also examined were the temporal trends in the growth of the 7.5-minute series of more detailed 1:24,000 maps. Because of aerial photogrammetry, spatial coverage of the 7.5-minute series advanced much more rapidly than for the 15-minute series, begun in an era of plane-table surveys and topographic field sketching.

The chapter also examined advances in aerial survey, including color-infrared imagery developed by the military for camouflage detection and electronic sensing systems, including active side-looking airborne radar (SLAR) systems as well as passive multispectral scanners. Image processing techniques developed with satellite remote sensing include: the simple parallelepiped classifier and more sophisticated classification algorithms, resampling to remove geometric distortions, edge enhancement to sharpen detail, and smoothing enhancement to remove the effects of "spikes" of high or low brightness. Remote sensing not only revolutionized the mapping of land cover and land use but held out the possibility of more accurate choropleth maps of population density computed by dividing county populations by the amount of residential land.

The chapter concluded with a brief discussion of mapping policy. More so than earlier mapping techniques, remote sensing raised issues of tradeoffs and privatization. At one level, civilian-oriented remote sensing programs like Landsat could be optimized for geologists or agriculturists—that is, to serve scientists concerned with geologic structure and petroleum exploration in contrast to scientists focused on vegetation and the world food supply. And of course there was the inherent conflict between civilians eager for the detailed imagery that was technologically possible and defense experts concerned that providing high-resolution imagery for civilian applications was a threat to national security even though our main opponent (the USSR) most certainly had excellent satellite spy systems. Amazing what a little competition from the French SPOT system did to that argument—not to mention the availability in the early 1990s of high-resolution satellite imagery from the former Soviet Union.

Remote sensing raised many other policy issues including the needs of academic researchers and other users less able to pay and the objections of Third World nations who charged that unauthorized sales of imagery of their national territory was a breach of privacy rights and international etiquette. Even so, "a tactfully managed satellite sensing program can be an effective instrument of international cooperation and regional development" (Monmonier, 1985, p. 109).

My fifth chapter, on decision support systems, began by looking at censuses and surveys for collecting demographic and socioeconomic data and moved quickly to the DIME (dual independent map encoding) data structures used to support address matching and computer mapping for the 1970 census. The chapter then briefly examined the history of computer mapping technology, which had advanced in two decades from comparatively crude line-printer maps to a variety of higher-resolution hardcopy displays based on the pen plotter, to interactive cathode ray tube displays with pointing devices and "user-friendly" menus. Of particular interest were plasma panels and other comparatively thin wall-panel displays as well as computer-controlled holograms.

The chapter turned from display to data in a section on National Atlases and Data Banks. After a concise look at the history of national atlases as instruments of planning, discovery, and education, I proposed that "modern telecommunications and data base technology will radically alter the organization and operation of national atlas programs," with the paper atlas "secondary to the digital cartographic data base from which it will be derived" (Monmonier, 1985, p. 136). The forecast included data transmitted by "wire or airwaves," more timely analyses in home or office, an improved cost-benefit ratio, and a fuller role for the private sector. Information policy would become a significant policy issue for cartographers and geographers, with free or low-cost public access a key issue.

Equally troublesome was the need for coordination, as much to thwart the easy addition of misleading poorly documented information as to provide open access to users. "Ready availability does not guarantee quality," I noted (Monmonier, 1985, p. 137). "If poorly controlled, an easily accessible data base may do more harm than slower, more traditional mapping methods" (p. 137). Also important was coordination with state and local agencies, with the possible addition of regional atlases and electronic databases. States would want their own electronic atlas systems, and state and federal systems would need to learn to talk to each other.

The next section addressed turnkey systems, mapping software, and usability. Of particular concern were the default options by which software developers gave naïve users a success experience by imposing standardized design decisions, often of dubious value. Nowhere was this more evident than in statistical mapping software that instantly generated colored five-category choropleth maps based on an equal-intervals classification. "Cartography as a profession," I noted, "should be concerned with the inventory and comparative evaluation of mapping software, with the clear and comprehensive documentation of program goals and system operation, and with the proper training of program users" (Monmonier, 1985, p. 142). Although cartographic journals have been rigorously reviewing software for nearly a decade, the profession today seems as powerless against stupidly designed software as it was against the flagrant misuse of the Mercator projection.

The final section, on Standards, Cooperation, and Shared Benefits, offers an optimistic note. In a broad plea for efficient documentation, compatibility of data and software, and widely recognized data exchange formats, I called for institutional guarantees that data are reliable, complete, and valid. Although standards offered some hope, "standardization can be both good and bad" (Monmonier, 1985, p. 143). In particular, I warned of a "hasty, politically expedient imposition of standards [that] might greatly lower the benefits of coordination." Like so many things, the effectiveness of standardization depends on how well it is done.

Chapter six, titled Map Publishing and the Digital Map, began with a brief examination of two earlier innovations with broad effects on cartography—namely, printing and photographic engraving. Of particular interest were unique cartographic adaptations such as wax engraving, which linked letterpress printing with map drafting through a nineteenth-century process of electroplating. An efficient method for rendering curved type as well as standardized point and line symbols, wax engraving gave railroad and textbook maps a distinctive look.

A more recent cartographic innovation, negative scribing with plastic film and "peelcoats" reached its heyday in the 1970s. Useful for producing cartographic layers known as "feature separations" and "color separations," this technology dominated advanced classes in map design and reproduction. And for a decade or so before the advent of the high-resolution imagesetter, digital map-production technology focused on automating the manual aspects of negative scribing. By the early 1980s, though, it was apparent that scanners would capture existing hardcopy cartographic images, while sophisticated commercial mapmakers created (and stored) new ones electronically.

In a section on Computer Memories for the Digital Map, I looked at electronic storage media ranging from cassette tapes and floppy discs to semiconductor memory and computer-searchable laserdiscs (videodiscs)—technology able to "place a sizable map collection in millions of homes" (Monmonier, 1985, p. 163). And in a section titled Glass Threads, Networks, and Videotex, I examined an emerging technology that promised maps a wider role in such information services as "city information, boating/fishing information, weather forecasts, real estate sales, and job searching" (p. 178). Even so, cartographic experiences in the development of printing and photography suggested this role would be secondary and passive rather than primary and active. "While not a prime innovator," I pointed out, "the map maker must be an efficient and innovative adaptor" (p. 178).

Chapter six concluded with a short essay on Maps as Software and a call for less emphasis on the paper map. "The Electronic Transition seems destined to progress to a stage at which maps are seldom composed on paper or similar [hard-copy] graphic media.... With time," I argued, "almost all cartographic data will be captured electronically, at their source, through photogrammetry or satellite remote sensing, or from computer systems for processing census results and other administrative data." Consequently, "a prime casualty of cartography's Electronic Transition will be the attitude that the map is a printed product.... [And although] it might be too soon to forecast the demise of the paper map, paper clearly [would] become less important as a storage medium and vehicle for geographic information.... [In slightly different words,] the paper map might not be dead, but the digital map will greatly alter where, how, and when paper maps are printed" (Monmonier, 1985, pp. 178-179).

THE BOOK'S CONCLUSIONS

The final chapter of the book was an opportunity not only to collect various observations from the earlier chapters but also to speculate more broadly about the future of maps, mapmaking, and mapping policy. I began with an attack on cartographic Darwinism: the naïve assumption "that maps will be better—more accurate, more timely, more accessible, more aesthetic, more tailored to user needs—simply as a result of high technology." More so than ever before in the history of cartography, the greatest challenge was institutional—the need for effective management and organization. "The potential for better maps has never been greater," it was clear, "yet neither has the threat of dismal, expensive, embarrassing failures" (Monmonier, 1985, p. 181).

The key issues involved public policy, not technology. Prime concerns in the early 1980s (and today as well) were privacy, public access, and cost recovery. Electronic linking of heretofore segregated records and high-resolution satellite sensing systems opened new avenues for questionable snooping on citizens by government and private individuals alike. Yet these tools might prove at least equally adept in legitimate attacks on crime and environmental pollution. Even so, who should have access to these and less sensitive data and at what price? Because electronic geographic data can be costly to develop, private developers need copyright protection. In the early 1980s, though, politicians and federal bureaucrats were beginning to think about a variety of radical strategies—radical for the United States, at least—including copyright protection for federal databases and privatization of heretofore public data-collection activities like the National Weather Service. Driving much of this thinking was recognition of the enormous value of geographic data to corporations that could well afford to pay for much more than the marginal cost of printing and distribution. Yet equally apparent was the difficulty of establishing a schedule of charges that provided fuller cost recovery yet accommodated the needs of academic researchers and other citizens with much shallower pockets. And turning mapping over to a for-profit corporation might well lead to neglect of areas with limited sales potential. To safeguard the needs of scholars and hobbyists as well as to shield national mapping programs from "blind allegiance to cartographic Nielsen ratings," I proposed (slightly tongue-in-cheek) a National Endowment for Cartography.

Coordination of mapping was an important policy need, which federal officials traditionally dealt with through interagency committees. Was it not time, I asked, for a major cabinet-level realignment, such as the consolidation of all mapping activities in a new Department of Natural Resources? Such proposals were by no means new, though, and I was hardly optimistic, especially about the likelihood of stronger links between topographic mapping on the one hand and demographic and economic censuses and surveys on the other. Although the military and natural resource agencies in the departments of Interior and Agriculture had a long history of communication and cooperation, obvious ties between mapping policy and statistical policy were markedly weaker.

Another concern was the growing role of private enterprise, which even without privatization would have substantial impacts on mapping.

Especially powerful was the multinational corporation, with needs to explore and integrate its operations "nationally and internationally without regard to political boundaries" (Monmonier, 1985, p. 188). Although largely an afterthought, the often subtle cartographic role of multinational corporations seems an intriguing topic for at least one doctoral dissertation on the history of late twentieth-century cartography.

To professional colleagues, my next section on Security and Digital Data must have seemed like science fiction if not outright hallucination. A clear drawback of electronic storage was the dual threat of "nuclear attack and the malevolent prankster," I wrote (Monmonier, 1985, p. 189). Like other forms of electronic data, digital cartographic information was vulnerable to electromagnetic pulse (EMP), whereby a high-voltage wave produced by a high-altitude nuclear explosion could shut down the electric power grid, disable telecommunications, and wipe out fragile circuitry and electronic storage media. Equally problematic, albeit in a wholly different way, was the capricious hacker who might move Cleveland into Lake Erie, delete important obstructions from aeronavigation charts, or enlarge his or her own lot at the expense of a neighbor. Like other electronic information, cartographic data must be defended against tampering and EMP.

A section on Preservation and the Historic Record addressed another challenge of cartography's electronic transition. Despite the vulnerability of paper to heat and time, paper maps are more easily collected, cataloged, and preserved than their electronic counterparts. Because hard-copy electronic storage is far from permanent, digital data must be recopied periodically. Moreover, preservation of electronic maps also requires preservation of display software and associated operating systems. Especially troublesome is the geographic database that is updated on a more or less continuous basis. Although edits and other changes might be archived so that any desired cartographic snapshot can be reconstructed, the map author or database administrator must make a conscious effort to preserve the cartographic record.

But what exactly does "cartographic record" mean in the digital era? I am not aware that any library or archives is systematically preserving late twentieth-century electronic cartography. Yet the challenge is enormous because an adequate historical record would include not only maps, data, software, and other artifacts but also information on how people, companies, and governments are using cartographic data. Future historians of cartography can benefit greatly from efforts to gather oral histories, institutional records, reports of participant observation, and recordings of interactive map analysis sessions. The history of cartography, unfortunately, seems too heavily committed to an antiquarian focus on the field's more distant past. And even unsystematic collectors short-sightedly avoid contemporary maps.

My final section on Humanistic Challenges addressed design, aesthetics, and the growing number of do-it-yourself mapmakers empowered by software and digital data. Unencumbered by either intelligent software or cartographic training, untrained users can be viewed as a threat to both themselves and other equally naïve users of their creations. This view, of course, is sometimes attacked in these postmodern times as the elitist hand-wringing of "the professional" with an economic and ideological stake in cartographic education—a charge not without merit. Even so, perhaps the greatest scholarly challenge of cartography's electronic transition was the apparent democratization of mapmaking that not only spawned millions of poorly designed maps but gave hundreds of thousands (at least) of novice mapmakers the opportunity to create potentially impressive cartographic artwork with crisp type and authoritative symbols, and to easily integrate maps with writing. Although I didn't emphasize this point, cartography's electronic transition offers the potential at least of a philosophical-cognitive revolution in how we think about and describe spatial relationships.

CRITICAL REVIEWS

Before closing, I want to address two fairly obvious, but nonetheless important, questions: How was the book received? And what do I wish I had treated differently?

First, the book's impact, which can be assessed in part through an examination of published reviews. Some of the two hundred free copies, struck responsive chords with book review editors, and critiques appeared in most (if not all) appropriate journals in geography and cartography, including *The American Cartographer*, the *Annals of the Association of American Geographers*, the *Bulletin of the Society of University Cartographers, The Canadian Geographer*, the *Cartographic Journal, Cartographica, Computers and the Social Sciences, Environment and Planning A, The Geographical Review, Geography, The Journal of Geography, The Photogrammetric Record, The Professional Geographer*, and *Technology and Culture.* More gratifying, most reviewers seemed pleased, although some were more enthusiastic than others, and even enthusiastic ones were a bit picky at times.

I kept track of reviewers' assessments by extracting their most positive and most negative comments as well as by rating each review *A, B, C,* or *D* (all very scientific, of course). Fortunately, there was no need for an *F* category—in the mid-1980s, that needlessly obtuse ritual whining known as postmodern critique had little interest in maps and geography. By my count (and you'll have to take my word for this), the book earned six *A*s, twelve *B*s, one *C*, and one *D*—a skewed distribution not unlike the grades I award in upper-division courses in advanced map design or geographic analysis.

The most enthusiastic reviewers not only acknowledged the book's clarity and timeliness but agreed that maps were due for profound change, and that cartographic scholars had seriously neglected the importance of policy. As an illustration of an "*A*" review, Michael Blakemore (1986), writing in *Environment and Planning A*, opined: "The joy of this book is that it provides a scholarly synthesis of the past as well as posing a wide range of questions about future issues. . . . It becomes increasingly clear from this excellent book that digital cartography throws up issues at such a rate that society feels it difficult even to react, let alone think the issues through logically" (p. 283).

The "*B*" reviews typically balanced positive comments with doubts or reservations. For example, Alan MacEachren (1986), writing in *The American Cartographer*, enthusiastically stated: "This book is unique in both its topic and perspective . . . this is a book that belongs in every cartographer's library. It contains opinions on cartography's future that deserve consideration by everyone involved with making, studying, and using maps." Yet he was critical of its content and focus: "As an introductory text, the book is rather narrow in scope. . . . The emphasis on national mapping policy and programs, while justified, so dominates the book that a beginning student might assume that all significant cartographic developments take place in the federal government."

The view that book-length essays on cartography are perforce textbooks accounts for a number of less than laudatory comments in the two "*C*" and "*D*" reviews. The "*C*" review—by a graduate student (Noronha, 1986) whose advisor (ironically) penned what I consider an "*A*" review (Goodchild, 1987)—had little positive to say beyond noting that "the language is clear" and that the "wealth of factual detail tucked between the lines . . . makes for a comprehensive historical perspective" (p. 309). The reviewer was deeply disappointed by the omission of such theoretical concepts as "smoothing, Fourier analysis, and fractal geometry" and by the dismal green dust jacket, the aesthetically mediocre graphics, and the lack of color illustrations. And the "*D*" review (Slocum, 1986), while conceding that: "Generally, this book does meet its intended goal," and concludes that "it is unlikely that [the book] will function well at the introductory cartography level because it is too broad in scope. It is more appropriate for a history of cartography course, or possibly a computer cartography seminar. This book might also be useful in a history of science course because it discusses a number of technological advances ancillary to cartography" (p. 38). Although I agree with, and even applaud, this assessment, I obviously should have emphasized more strongly my intent not to write an introductory textbook.

REGRETS AND LOOKING AHEAD

What else would I have emphasized? Two things, principally: an increased facility for integrating graphics with written text and the advent of dynamic experiential maps able to free users from ossifying single-map views.

I addressed integration more satisfactorily four years later in another university press book, *Maps with the News: The Development of American Journalistic Cartography.* The final chapter concluded with the observation that personal computers and mapping software held the promise of richer geographic descriptions, interpretations, and explanations by journalists and writers able to link both media with ease and think graphically as well as verbally (Monmonier, 1989, pp. 246-47). This consequence of cartography's electronic transition is clearly deeper and more far-reaching than my earlier forecast of a "'de-massified' cartography" (Monmonier, 1985, p. 172).

Equally significant is the likelihood of experiential maps. Defined as dynamic displays with which the viewer can readily interact, experiential maps are much more than interactive mapping software: guided by scripts and user profiles, an experiential map can explain a process or act out a temporal event with terminology, symbols, sequences, and geographic foci adapted to the viewer's interests and experience. At its simplest level, the experiential map might reveal geographic nuances hidden by a traditional static map. At more advanced levels, it can orient a viewer to a new atlas or electronic database, help the user comprehend complex concepts in physical or human geography, or assure that an analyst will not overlook a potentially meaningful spatial pattern. Although my 1985 essay forecast an increased use of both animation and interactive mapping (Monmonier, 1985, pp. 137-42, 163), more recent developments, such as graphic scripts (Monmonier, 1992), suggest profound changes in how maps can engage users in a search for knowledge and understanding.

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