A History of Distributed Mapping

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My intent in this paper is to answer two questions: what were the principal events in the development of distributed mapping, and how should a narrative of its development be written? Distributed mapping is a mode of cartography arising from the convergence of the World Wide Web, GIS, and digital cartography. It marks a significant break with traditional cartography because (1) the set of rules that shape the map archive are being fundamentally altered; (2) the distributivity of spatial data, their analysis and visualization are at unprecedented levels; and (3) new forms of interactivity are emerging. After discussing some theoretical issues in the history of cartography, I locate the multiple origins of distributed mapping in the work on animated mapping during the quantitative revolution in geography and the availability of computing power from the 1960s through the 1980s. The technology is a series of non-deterministic negotiations with resistance leading to delays in implementation, back-tracking, and multiple avenues of exploration. The popularization of the World Wide Web during the latter part of the 1990s brought commercial attention to distributed mapping, not as cartography, but as a support service for travel sales channels. Commercialization will detach distributed mapping from academic geography as it did with GIS before it. In conclusion, I outline the forseeable research issues for distributed mapping.

INTRODUCTION

This paper addresses an important new development that might fundamentally change the way in which spatial data are accessed, analyzed, and communicated. The explosion of the Internet and its convergence with geographical tools have made spatial data display and analysis readily available to a wide, asynchronous audience. Also labeled "Internet GIS" (Peng 1999), "GIS Online" (a regular column in trade journal *GIS World*), and "Web-based GIS," distributed mapping is a highly dispersed, multiuser activity with conceptual ties to the distributed databases of the 1970s.

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Much distributed mapping currently occurs on the Internet or the World Wide Web, but it can occur elsewhere too, and historically did so. For example, a distributed mapping environment could be made available via an Intranet or as a hybrid CD-ROM/network product. The term "mapping" is preferable to another suggested term, "distributed geographic information" (Plewe 1997) because the latter included the distribution of non-interactive spatial databases and is associated with a particular technology, GIS. By contrast, distributed mapping is not a technology but a strategy. In addition, I emphasize the creative problem-solving and visualization capabilities of mapping as an interactive process of spatial knowledge discovery and creation. Whatever its technological manifestation, mapping is likely to endure as a spatial problem-solving activity.

Although distributed mapping is recent, a history of it can be justified by its extremely rapid rise, which parallels the growth of the Web itself. Second, it is little understood, and its implications and research issues (e.g., on map design, on geographic education, or on how space is represented) are not yet fully identified, let alone solved. One way to increase understanding is to examine the way distributed mapping is historically related to developments in cartography, GIS, and geography, as well as to larger societal developments such as the Internet.

DEFINITION OF DISTRIBUTED MAPPING AND SCOPE OF PAPER

What is distributed mapping? The critical concepts are:

1. Access to spatial data processing and visualization tools to a dispersed audience
2. Interactivity with map or a spatial database
3. Spatial problem solving or visualization need.

A "distributed" system is one which has elements of dispersion (L. *dispargere* to strew) and dispensing (L. *dispendere* to weigh out). In distributed mapping maps are therefore spread out (dispersed) but also (inter)actively allotted on demand (dispensed).

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A typical implementation of a distributed mapping system would comprise a spatial data server, a network, and access via client computers (Figure 1).

SERVER ——————— NETWORK ——————— CLIENT(S)

Figure 1. Idealized schema for distributed mapping.

This is the simplest and most inclusive model—there are many variations in practice (Plewe 1997), some of which are discussed in this paper. In the simple scheme illustrated here, the Internet or the Web can comprise the network. These two networks are not identical—the Internet was developed during the 1960s, whereas the Web was established in the 1990s as a more user-friendly interface to parts of the Internet (see Hafner and Lyon 1996 for an excellent history of the Internet)—although both transmit packets of data using TCP/IP (Transmission Control Protocol/Internet Protocol). In Figure 1 spatial data are served out across the network and interactively accessed by multiple clients. The server implementation can vary, with the HTTP (hypertext transfer protocol) and map/GIS servers separate or combined. If most of the processing is done by the client, the term "thick client" is sometimes employed, but if the server assumes the bulk of processing, the client is considered "thin" (Peng 1999).

An interesting variation on this scheme is provided by Public Participation GIS (PPGIS), an outcome of the Society and GIS Initiative 19 (Pickles 1999) in the National Center for Geographic Information and Analysis (NCGIA). The goal of PPGIS is to provide access to the full functionalities and data of a GIS at the local level without necessarily employing a network. The GIS may be in a mobile van that visits several neighborhoods or returns periodically to the same neighborhood. Because mapping capabilities are distributed to a wide and multiple audience who interact with the data (e.g., in making local planning decisions during road construction), it is appropriate to call PPGIS "distributed mapping." This example also illustrates the inappropriate narrowness of the term "Internet GIS" (Peng 1999).

This paper covers distributed mapping, with an emphasis on interactive systems that provide massively distributed but individually tailored maps. It is not a history of digital cartography as a whole. Obviously there are overlaps with related developments, such as mapping software and the history of GIS, but I do not consider these here. Equally obvious, this paper is merely an initial attempt to explore the subject, and much more work needs to be done.

CRITICAL THEORETICAL ISSUES OF DISTRIBUTED MAPPING

Theoretical issues raised in the literature complicate the work of anyone attempting to offer a history of a cartographic practice. These include the relationship between maps and power, representation under empiricist or constructivist approaches, the notion of contingency in the development of maps and mapping practices, and questions of how mapping environments produce spaces and places.

There are a number of possible responses to these issues, and cartographers and geographers have at one time or another adopted them all:

1. The issues are irrelevant, are not accepted, and need not be engaged (Theory Avoiding);
2. The issues are already known, have been accepted, and need not be further engaged (Theory Embracing);
3. The issues are important, are still unresolved, and need to be engaged (Theory Engaging).

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The labels in parentheses reflect fundamental differences in outlook and approach. If you believe that (1) "The issues are irrelevant, are not accepted, and need not be addressed at all," then theory simply gets in the way of the job. If you could not imagine discussing with your students or your boss Derek Gregory's observation that "advances in GIS . . . assume that it is technically possible to hold up a mirror to the world and have direct and unproblematic access to 'reality' through a new spatial optics" (Gregory 1994, 68), you are a Theory Avoider.

If you are a member of the second constituency, the ones who respond with (2) "The issues are already known, have been accepted, and need not be further addressed," you will recognize in Gregory's remarks an attack on the correspondence theory of representation implicit in cartographic practice for most of the second part of the twentieth century. Correspondence theory is the idea that a neutral, objective representation of reality can be made in maps, language, or other sign system, and that it is our goal as cartographers to do so. You may also feel that this critique is already being successfully mounted against cartography via the work of, *inter alia*, Brian Harley, Denis Wood, Matthew Edney, and John Pickles. You are a Theory Embracer.

Members of these first two camps seem to face in opposite directions. For every worker in an intellectual environment in which theory is only a distraction from the problem-solving capabilities of GIS, another scoffs at the idea that cartographers still employ the map communication model. For the most part, these constituencies have occupied different realms of discourse, and although various attempts (e.g., Pickles 1995, 1997; Wright *et al.* 1997) have been made during the 1990s to bring them together, these efforts produced little intellectual movement. To clear decks and define terms is an important step in critical engagement, but as yet, the fray has not be joined in a wider sense.

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Members of the third group who respond "The issues are important, are still unresolved, and need to be addressed" may be forgiven for having a sneaking admiration for Eagleton's adage that "hostility to theory usually means an opposition to other people's theories and an oblivion to one's own" (Eagleton 1983, viii). Theory Engagers believe that the other two groups lack critical engagement with theory: Group 1 because it prefers to *ignore* theory and Group 2 because it seems too *entranced* by it. Members of Group 3 want to argue with the technological determinism of

Neil Smith's assertion that the "Gulf War was the first full-scale GIS war" (Smith 1992), as theory gone too far, but also feel that most cartographic practices, including distributed mapping, are under-theorized.

This paper has been written to make membership of this third group seem our best choice in understanding mapping practices and their history. For we Theory Engagers, although the first two groups have produced some useful arguments, on the whole we find that Theory Avoiders are oblivious to their own theories of the correspondence theory of representation (which with Group 2 we see as discredited), while Theory Embracers too often see cartographic practices as *necessarily* technicist, militaristic or engaging in that baleful "spatial optics" of surveillance (which with Group 1 we see as throwing the baby out with the bathwater). To engage with theory in cartography is to seek a middle ground between the non-theoretic and the overly theoretic.

Theory in the History of Distributed Mapping

In order to understand why we might want to be a Theory Engager in understanding the history of distributed mapping, I have employed some concepts and terminology from work by Matthew Edney (1993, 1996, 1997). Edney's work is embedded in a discourse associated in the history of cartography with Harley, Pickles, Wood, the *History of Cartography* project itself, (edited by Harley and Woodward), and the Monmonier of "carto-controversies" (Monmonier 1995), which emphasize maps as social constructions. Edney argues that the discipline of cartography has adopted a monolithic view of the history of cartographic practices. This view sees cartography as the progressive enlargement of information collected about the world—a spatial database. The database has several notable assumptions: it is scaleless; geographic facts have single geometrical locations ("location might be inaccurate or imprecise, but it is never ambiguous; each place exists in only one location" Edney 1993, 55); the data are commensurable (data can be added together or compared, and do not contradict each other—an assumption I argue leads to the current focus on "inter-operability" in GIS); the database is enlarging and becoming "better" (more comprehensive, precise and accurate) over time; and the facts of the world can be read off from nature and collected (empiricism, or technically in positivism *le reel*). Note that this last assumption appeals to the correspondence theory of truth behind the map communication model and that Theory Avoiders hold most of these assumptions.

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Edney argues that it is time that we drop these assumptions, because they gloss over a more productive way of seeing cartographic history as the evolution of different "modes" of mapping. Each mode of mapping is intimately tied to social, cultural, and technological relations, which are contingent on particular times and places. For example, after the Renaissance the three primary modes were chorography, charting, and topography, reflecting mapping activity at various scales. By the early eighteenth century, however, these modes had merged into a single mode of mathematical cosmography (i.e., the geometrical and astronomical processes of mapping). "This merger was effectively complete by 1750: geographic data were held to be conceptually scaleless so that the scale-based distinction between chorography and special geography dissolved" (Edney 1997, 43). This period of unification lasted until approximately the early nineteenth century, when cartography again fragmented into several modes, including thematic mapping, systematic mapping, and the revival in new forms of chorographic, charting, and topographic activities.

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Is progressivism in cartography simply a "straw man which can easily be knocked over" (Monmonier 1999, 235)? After all, technology has yielded many benefits and advantages, including the high customization of distributed mapping, as Monmonier points out. However, non-progressivists such as Edney do not gainsay societal benefits but are concerned with the account we give of those benefits. The account they challenge says that progress takes place inevitably and linearly over time (without retrenchment, ruptures, dead ends, etc.); that it is based on a model of mapping which is empiricist; and that a database of commensurable data can gradually be built up. True, this aspect is fading thanks in part to the History of Cartography project, but there were many histories prior to this (and in part what it was written against, see Edney 1999, esp. p. 2) which adopted the linear model. And some recent textbooks (e.g., Tyner 1992, 4-5) still offer it.

In Edney's view, no particular mode is historically privileged over the others. Instead, the various modes are inter-related, contesting, and dominant at different times. Each mode may emphasize different cartographic techniques (the survey, the traverse) or different conceptions of space (geometrical, commodified, or personal). Edney's account is non-telelogical in that it does not see cartography as getting better and better maps in the sense of getting our maps to reflect reality more truthfully. Instead maps are a historically contingent set of relations adapted to their environment: "a map is a representation of knowledge; the representation is constructed according to culturally defined semiotic codes" (Edney 1996, 189). On this view, there is no such thing as a temporally stable, historically transcendent answer to the question "What is a map?" It would be impossible to give "a" definition of a map, yet very easy to offer multiple, competing ones (Andrews 1996).

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One reason Edney's viewpoint is useful is that it forces us to confront contemporary mapping in the same evolutionary light, and to discard determinist models of technology. Using an argument developed in a discussion of the ethics of the Internet (Crampton 1999a), I argue that technologies such as distributed mapping should not be assigned inherent logics or powers, as when the Internet is condemned as inherently surveillant or praised as inherently emancipatory. On the contrary, technologies are part of intellectual traditions, and are constituted through sets of mutual relations with society. Those relations may be constraining or emanci-patory, but are not *necessarily* either. Contrary to the more provocative critics of GIS who warn of a powerfully dominating technology (Smith 1992; Pickles 1991), I find it more useful to think of power and technology not as domination but as something that produces resistance and requires negotiation of its implementation (Foucault 1980, 142). Thus a technology such as distributed mapping, GIS, or the Internet becomes a site of negotiation and contestation with those who resist *and* modify it, as when, for example, information technology threatens personal privacy. I also argue that scholars and practitioners should take part in this negotiation, as Internet activists, and shape distributed mapping into the form they most prefer (Crampton 1999a).

In examining the history of distributed mapping I therefore wish to apply the following concepts: distributed mapping is a (socially) constructed "mode of cartography" (in Edney's phrase), whose history is best written non-progressively without recourse to the empiricism of the map communication model, and without a search for "the origin" of a practice or a simplistic, linear sequence of influences. Delays, discontinuities, and retrenchments are likely to be found. Power and resistance circulate through a technology and its social relations. In the next section I explore the relevance of these concepts to the historiography of distributed mapping.

THE HISTORY OF DISTRIBUTED MAPPING AS A MODE OF CARTOGRAPHY

Distributed mapping is an emerging area that represents one of the most interesting outcomes of the convergence of spatial technologies such as GIS, remote sensing, and digital cartography with the World Wide Web (MacEachren 1998; Plewe 1997). This convergence combines the methods and techniques of interactive mapping and spatial analysis with the distribution of functionality and resources in new and provocative ways. Two recent developments in particular have led to a surge of interest in distributed mapping by cartographers, the GIS community, and the commercial sector. The first of these is the potential afforded by "user-defined" and "on-demand" mapping functionality. User-defined mapping refers to user control of data coverages, perspectives, speed of animation, and other facets of the map.

"Two recent developments in particular have led to a surge of interest in distributed mapping . . . 'user-defined' and 'on-demand' mapping; and interactive three-dimensional represenatations."

Monmonier was one of the first cartographers to recognize the importance of distributed user-defined maps when he spoke of "individually tailored, one-of-a-kind maps" being sent electronically (Monmonier 1985, 172). Monmonier applied the suggestions of Toffler on the "de-massifying" effects of technology. De-massification is a feature of post-Fordism (extremely flexible modes of production and labor deployment), and distributed mapping's capability to create individualized maps means that it is a form of post-Fordist cartography. This suggests interesting avenues of research into the labor practices of distributed mapping.

In a previous book (Monmonier 1982) had also noted the outgrowth of distributed databases from remote time-sharing computing during the 1970s. In some of these early distributed databases a limited degree of interactivity and thus user-definition was possible. One of these was the US federal government's DIDS or Decision Information Display System, which had been developed by NASA, the Department of Commerce, and the Census Bureau. DIDS was meant to share and distribute data to many agencies, legislators, universities and other users (Monmonier 1982, 146). Although DIDS underwent extensive testing, it was never installed because of the cost of specialized computing hardware and a lack of demand for its data. Yet many of its functions can be found in today's distributed mapping systems. For example, DIDS had progressive zooms or scale changes, analogous to MapQuest's maps. DIDS was probably ahead of its time.

On-demand mapping refers to maps that the user creates at the moment of need, in contrast to previously compiled maps collected in archives or map libraries (Crampton 1999b). Indeed, the rules under which maps are created and archived, discussed, appropriated, forgotten or remembered have undergone a radical break. Maps are used quite differently in distributed mapping, as we shall see below. Transience and ephemerality are hallmarks of online mapping: neither printed out nor saved, maps exist for minutes or hours rather than centuries. And the typical map library has no record of a map's creation or use.

In this context (the archives as the set of rules) it is useful to apply the concept of an "archeology" as described by Foucault (1972). An archeology is an attempt to uncover the historical rules of the formation of knowledge seen as a set of discourses. How are some things said or not said, conserved, remembered, or appropriated? Further, what are "its modes of appearance, its forms of existence and coexistence, its system of accumulation, historicity, and disappearance?" (Foucault 1972, 130). Foucault's focus on discontinuities, displacements, and transformations in the history of systems of thought are relevant to contemporary cartographic history.

In particular, user-defined (individualized) and on-demand (transience) approaches to mapping distinguish traditional cartography (with its emphasis on communication and static *maps*) from contemporary developments in interactive mapping and distributed GIS that emphasize mapping *environments* in which the maps themselves are fleeting and transient.

The second development is the capability of an interactive digital environment to handle distributed three-dimensional representations, sometimes referred to collectively as "Web3D." This latter capability has been much aided by several technical developments for world-building, which can be distributed via the Internet. Three-dimensional online mapping is an extension of both traditional static 2D maps, and 2D interactive online maps, whether from GIS vendors or online mapping services (Crampton 1999c). A 3D mapping experience takes advantage of the exploratory, highly interactive nature of GVis (geographic viusualization). It can also provide a "co-space" that can be occupied by more than one "avatar," or representational person, therefore allowing interaction between users. The goal is not a single "best" map but a fully realized spatial environment—in effect, the user can enter the map itself. At the moment, though, this is nothing more than an intriguing possibility.

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In brief, distributed mapping (i.e., 2D or 3D) consists of tools, methods, and approaches to using, producing, and analyzing maps via the Internet, especially the World Wide Web. It is highly user-oriented, characterized by a distributed ability to create user-defined maps on demand. These features enable distributed mapping to be highly interactive and exploratory. Compared with traditional static maps, most distributed maps are neither printed nor saved, with important implications for map collectors as cartographic archives.

Distributed Mapping in Historical Context—Early Developments

Edney's notion of cartographic modes allows an insightful historical assessment of distributed mapping and its effect on the archive. Figure 2 illustrates the merging and branching of the various fields that converged in the 1990s to form the current picture of distributed mapping, especially cartography, GIS, and the Internet (then later the World Wide Web). Due to space limitations, I will focus on the more significant events and their implications.

Cartography and GIS

Experiments in digital mapping were first made during the 1960s and 1970s. These maps were not massively distributed, although mapmaking software such as SAS/GRAPH and SPSS was available for mainframe computers. Geography was well into a period of intellectual growth, later known as the "quantitative revolution," that emphasized systematic analysis (Gould 1979; Billinge, Gregory and Martin 1983; Livingstone 1992, esp. chapter 9) and computer display hardware was becoming widespread (Peterson 1995, 64 ff.). The quantitative revolution created an intellectual space for technical enquiry, and recent graduates of departments with an emphasis on spatial analysis shaped the field during the 1960s. The most important of these departments was the University of Washington, in Seattle. Also influential were the geography departments at Iowa, Chicago, Northwestern, and Ohio State, which initiated the field's flagship journal, *Geographical Analysis* in 1969. Notably innovative geographers include William L. Garrison, a Northwestern University PhD (1950), and a quartet of Washington PhDs: Brian Berry (1958), William Bunge (1958),

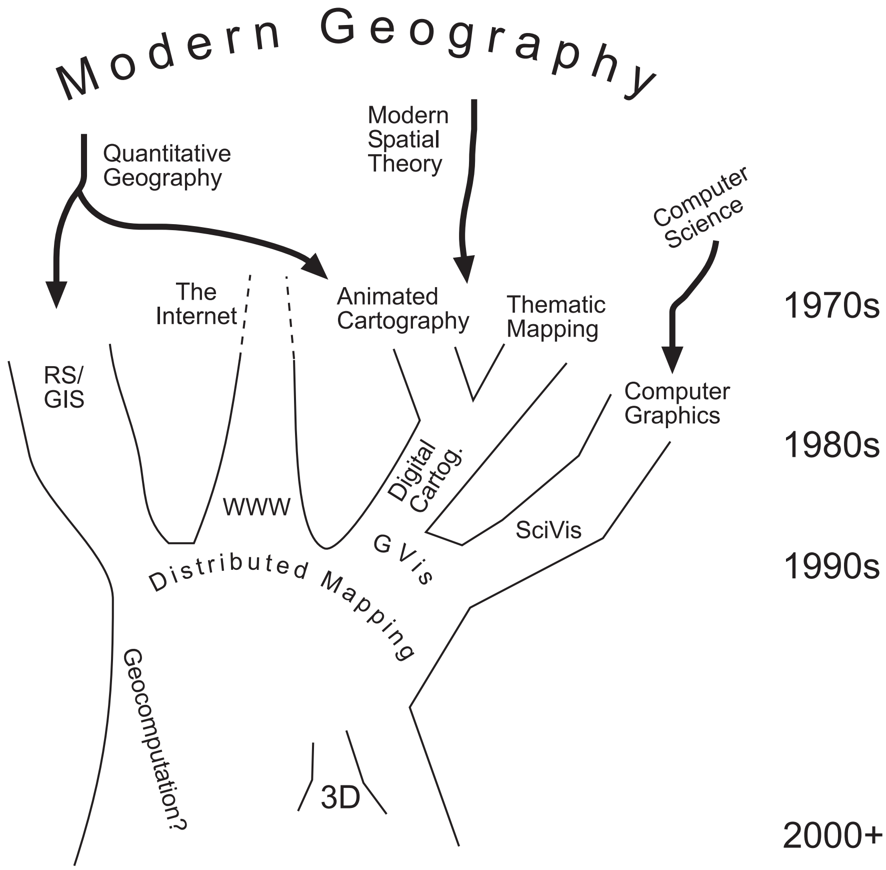

Figure 2. History and Development of Distributed Mapping as a Mode of Cartography.

Richard L. Morrill (1959), and Waldo Tobler (1961). In an early article, "On Automation and Cartography," Tobler (1959) discussed the map as part of a data processing system (the map as storage unit, output device, and so forth) and provided an intellectual foundation for computer cartography (Clarke 1995, 5). Bunge (1966, viii) credited Arthur Robinson for his initial thoughts on "metacartography," and several of the others acknowledged the migration models and spatial probability surfaces of Torsten Hagerstrand, a 1953 PhD graduate of the University of Lund.

Although these early experiments were not interactive maps, a paper by one of the most intellectually fertile quantitative geographers, Waldo Tobler (1970), revealed a latent interest in dynamic cartography. In a study of urban population growth, Tobler used film animation to visualize solutions to geographical problems as well as to explore spatial data, much the same as today: "the expectation . . . is that the movie representation of the simulated population distribution in the Detroit region will provide insights, mostly of an intuitive rather than a formal nature, into the dynamics of urban growth" (Tobler 1970, 238). His movie was based on an explicit model of population, so that changing the terms of the model would alter the rate of change of the urban growth and provide the theme for a new animation. Although Tobler did not discuss interactivity directly, his paper reflects a "mapping or visualization need." Even so, this is a far cry from the interactivity of systems able to respond in less than a second (<1s) (Crampton, forthcoming), and only later (late 1970s and 1980s) did researchers become interested in the techniques and concepts of animated and interactive mapping. Of particular note was the early involvement of military funding agencies, such as the Office of Naval Research, which

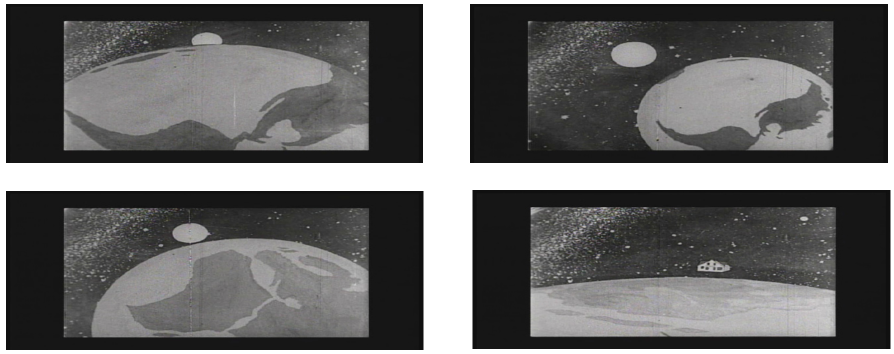

Figure 3. Very early animated "map" featuring a spinning globe. Source: Animation Legend*: Winsor McCay ©1993 Cinémathèque Quebécoise and Lumivision. Used with permission.*

sponsored a symposium on quantitative geography in 1959 and funded Tobler and others' work (e.g., the Harvard Graphics Laboratory) through the 1960s (Mark *et al.* no date).

Earlier efforts outside geography produced numerous (non-computer, non-interactive) cel animations for the public. Cel animations were first used in the film *The Sinking of the Lusitania* by the cel pioneer Winsor McCay in 1918. In Figure 3, a sequence from a 1921 animation *The Flying House* (also known as "Rarebit Dreams"), a flying house is shown circling a rotating earth (rotating the wrong way!). This may well be the first ever animated "map."

In an early study Thrower (1961) examined 50 short (~3 minutes) educational film sequences with cartographic cel animations made between 1936 and 1957. Although these animations lacked many important cartographic components, Thrower pointed out that animation is "unexcelled" for certain kinds of spatial relationships, especially for people conditioned on moving images in movies and TV (p. 28). He ended his discussion by pointing out that animation is not a substitute for static cartography, a point equally relevant to today's distributed mapping.

Although competent computer graphics hardware, available in the 1960s, fostered the more fully computerized compositions that quickly replaced frame-by-frame animation (Campbell and Egbert 1990), the most influential computer program of the decade did not support animation. SYMAP—the acronym means SYnagraphic MAPping, that is "acting together graphically" (Cerny 1972, 167)—was originally conceived in 1963 by Howard Fisher at Northwestern University and later at Harvard's Laboratory for Computer Graphics and Spatial Analysis in 1968 (Chrisman 1988). SYMAP performed geographic computations such as interpolation and point-to-polygon conversion and produced choropleth and isarithmic maps on the widely available line printer (Monmonier 1982, 50-65). Fisher, an industrial architect, established the Harvard Lab in 1966, with a grant from the Ford Foundation; the Office of Naval Research provided funding after 1969, when William W. Warntz, a leading quantitative geographer, became the Lab's director (Warntz 1983; Mark *et al*., no date).

The history of these technical developments is well documented. Especially useful are Monmonier's two books (1982, 1985), a paper by Coppock and Rhind (1991), a special issue of *The American Cartographer* (Petchenik 1988), and in the field of GIS, Foresman's (1997) *History of Geographic Information Systems* and the NCGIA Core Curriculum Unit on the History of GIS (Klinkenberg 1997). Other important developments during the 1960s and 1970s include the Census Bureau's DIME and TIGER databases, the CIA's World Databank II—later used by the first online mapping system, the Xerox PARC MapServer, established in June 1993—and the founding of ESRI, Intergraph and Laser-Scan. The history can be divided into several periods: the early pioneers (1960s); the role of the government agencies (1970s); and the commercial development period (1980s onwards). With the emergence of Web-based GISs, we are perhaps entering a new period of "user-defined" cartography characterized by user creation of maps on demand, using highly interactive systems (Crampton 1999b). These developments were technically and socially linked. For example, several researchers who developed the ODYSSEY system at the Harvard Lab moved to ESRI and became instrumental in the development of GIS (Chrisman 1988).

"The history of technical developments can be divided into several periods: the early pioneers (1960s); the role of the government agencies (1970s); and the commercial development period (1980s onwards)."

Despite the triumphs of computer-assisted cartography and GIS, delay and retrenchment marked the first years after the prescient papers of Thrower and Tobler. Hardware was a principal impediment as concepts emerged before the inexpensive computing power needed for implementation. Statistical software with mapping capabilities (such as SPSS and SAS-GRAPH) became widely available during the 1980s, but animation and interactivity lagged. Campbell and Egbert (1990) felt so strongly about the lack of progress that they wrote a critical article arguing that cartography had a long way to go if it was to do more than just "scratch the surface." This thirty years of stagnation underscores the relationship of mapping to larger societal developments (in this case sufficient computing power).

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The History of the Web and Contemporary Development of Distributed Mapping

The history of the Internet has received considerable attention, reflecting its high visibility during the 1990s among journalists, academics, and the public. The most incisive book on the origins and early history of the Internet is the study by Hafner and Lyon (1996), but—perhaps predictably—the most detailed narrative is an online timeline known as "Hobbes' Internet Timeline" (Zakon 1999). Although I will not delve into the history of the Internet, it is worth reflecting on the origins of the Web itself.

The World Wide Web (which should always be carefully distinguished from the Internet) formally originated in March 1989 in a proposal by a British physicist, Timothy Berners-Lee, working at the European Nuclear Research Center (CERN, an acronym of its name in French) in Geneva. The particular circumstances surrounding it were mediated through intellectual and social connections, and its work did not progress smoothly. The original plan for the Web was an information retrieval and ordering device. During the 1980s Berners-Lee had been searching for ways of organizing information for spatially separated scientists, who used different computing environments, spoke different languages, and worked on rapidly evolving complex systems. His solution was a distributed hypertext system that in 1989 he called "Mesh" (the term World Wide Web was substituted in 1990). Hypertext had received considerable attention in the 1950s and 60s through the work of an independent researcher Ted Nelson, whose own work was inspired in 1945 by presidential science advisor Vannevar Bush, who directed the Office of Scientific Research and Development. Bush's "Memex" was not physically implemented into any working system. But by the late 1980s renewed interest in hypertext among many computer scientists was apparent in a USENET newsgroup alt.hypertext, a special issue in 1988 of the *Communications of the ACM* (Association of Computing Machinery), and at least two conferences. Berners-Lee was aware of these developments, and modified an Apple HyperCard-like organizational system he had first developed in 1980 called "Enquire" to handle project management (Berners-Lee 1989).

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Put into place in 1990, these ideas generated little interest outside CERN. After all, hypertext had been around for more than forty years (perhaps earlier if rudimentary annotation systems such as the commentaries on the Torah are counted). What the Web needed was a way of making the ideas tangible and easy to understand. This came in the form of a graphical browser, Mosaic. Mosaic was the "killer app" for the Web, first for the X windows system under UNIX, then for the Mac and Windows. It was not the first client browser (this honor again belongs to Berners-Lee, who in 1990 wrote one called "WorldWideWeb" [no spaces, later renamed Nexus to avoid confusion]) but it was the first browser available to the public. Although now largely replaced by Netscape and Microsoft Internet Explorer, Mosaic initiated the era of the graphical browser in 1993, and the Web as we now know it had arrived.

Figures for Web usage confirm the network's rapid growth. Indeed, during the period of 1992-1995, the Web's share of traffic on the NSF's backbone network increased from zero to 26.3 percent, and rose in rank to first place (Table 1).

Date	**FTP as Percentage of Traffic (Rank†)**	**World Wide Web as Percentage of Traffic (Rank†)**
6/92	50.4 (1)	–
12/92	46.1 (1)	0.002 (186)
6/93	42.9 (1)	0.5 (21)
12/93	40.9 (1)	2.2 (11)
6/94	35.2 (1)	6.1 (7)
12/94	31.7 (1)	16.0 (2)
4/95*	21.5 (2)	26.3 (1)
[1999	~13 (n.a.)	~68 (1)]**

*Table 1. NSFNET Backbone Data: Proportion of Traffic in Bytes by Port (WWW = 80, ftp = 20). Other services not listed include finger, gopher, nntp, telnet, etc. Source: Compiled by author from archives at ftp://nic.merit.edu/statistics/nsfnet/. †Rank of proportion of packets. *The NSFNET backbone was disbanded in April 1995. **Source: Peterson (1999, 573) percentage of all Internet traffic.*

The trend has continued since 1995 as can be seen by the last line of Table 1. In fact, today's Internet is so congested (particularly with ".com" traffic) that a consortium of universities and business (the University Corporation for Advanced Internet Development, UCAID) has developed an advanced backbone network for "Internet2" member universities that offers sufficient commercial-free bandwidth to enable live online videoconferencing and other bandwidth-dependent scientific research. This is called the Abilene project.

"Despite this amazing growth, the Web is available only to a tiny fraction of the world's population."

Despite this amazing growth, the Web is available only to a tiny fraction of the world's population (see Table 2). This fact is sometimes forgotten in the hyperbole surrounding the Web and the Internet. Furthermore, access is highly constrained by geography, social status, age, gender, and other variables (Crampton 1999a). For instance, the Washington, DC area has been reported as the USA's most Internet connected region, with nearly 60 percent online. Globally, the average is only 5.4 percent for 2000. This disparity is known as the "digital divide."

As Figure 2 shows, the capabilities of the Internet first merged with those of GIS/cartography in the early 1990s. The first interactive mapping capabilities were established to test interactivity, rather than as cartographic or GIS applications per se. Not until the late 1990s were distrib-

Date	Online Population (millions)	As Percentage of World Population
1996	60	1.0
1997	100	1.7
1998	150	2.5
2000	327	5.4
2005	720	11.2

Table 2. Persons with access to the Internet as a percentage of total world population, all ages, 1996-2005. Source: US Census Bureau, NIU.

uted mapping systems established for the express purpose of providing GIS/cartographic functionality.

The earliest map server is the Xerox PARC (Palo Alto Research Center) server developed by Steve Putz to test Common Gateway Interface (CGI) scripts via the Web, and put online in June 1993 (Putz 1994). CGI is a method for external clients to execute commands interactively and remotely on information servers. Notably, the maps were created "on-demand" with the PERL scripting language according to a set of basic user inputs (latitude/longitude, scale, etc.) embedded in the URL, rather than serving images from a map archive. The on-demand maps were then served out via an HTTP process running on a Sun workstation at Xerox PARC (Figure 4). Basic usage statistics indicate that the Xerox PARC map server is highly popular, with some 130 million accesses since it started in June 1993 through summer 1999. Holding at approximately 60,000 map images per day, the level of access has not changed substantially since Spring 1996. For a while, though, the server was also accessible via a geographic name server (a service now alternatively available for US cities from the Census Bureau).

Archival information provides only a partial glimpse at the history of this innovative mapping environment. A record of the types of map in use, their geographic focus, and scale is not available. The conditions of knowing and storing this kind of information have been lost. We do not know, for example, what parts of the world are mapped or by whom. Are the maps used to explore events in the news (knowledge discovery) or to look up your hometown (knowledge confirmation)? What are the common scales used: small-scale (synoptic) or large-scale (local)?

"Are distributed maps used to explore events in the news (knowledge discovery) or to look up your hometown (knowledge confirmation)? What are the common scales used: small-scale (synoptic) or large-scale (local)?"

Other significant developers were the Bureau of the Census, which put its TIGER databases online in 1995 and the Digital Libraries Initiative, established in 1995 to promote cartographic interfaces for georeferenced data. A cartographic "front end" helps the user of a digital library search for images, maps, or other environmental data and metadata. The best known example is the Alexandria Digital Library (Buttenfield 1999). Other government agencies, including the U.S. Geological Survey, also provide distributed data, though not necessarily interactively. "Earthview" at CERN, another well-known service, produces about 60,000 user-defined map views per day (Peterson 1999). By comparison, the USGS, often thought to be the world's largest producer of printed maps, distributes an estimated 500,000 non-custom maps each week.

By 1996, commercial vendors had also recognized the potential value of distributed mapping, and were offering a variety of products in the marketplace. These products fall into two categories, the first of which consists of interactive map generators and online spatial data providers (true "online mapping"). These include MapQuest, which not only provides maps at its own site but also provides maps for Yahoo! and other Web sites; MapBlast!, provided by Vicinity Corp., a business services company that

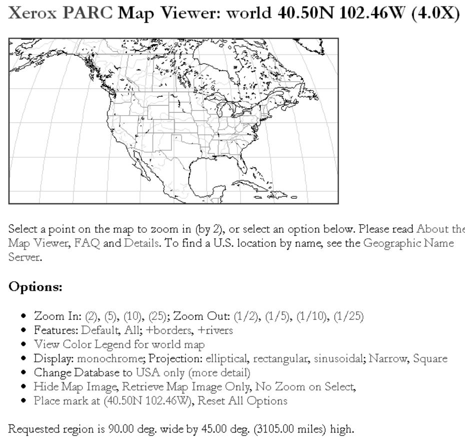

Figure 4. Illustration of Xerox PARC map webserver, the first online mapping environment.

uses data from Etak; mapping services associated with online phone and people directories, such as MapsOnUs, Switchboard, and BigFoot; and most recently a joint Microsoft/USGS product called TerraServer. A commercial implementation of the digital library concept, TerraServer offers a database of imagery via either a cartographic or a geographic name interface, and provides declassified Russian satellite imagery (SPIN-2, 2-meter resolution) for global images as well as USGS aerial photography (digital orthophotographs of 1-meter resolution) for the United States. Developed initially by Microsoft as an experiment in terabyte (trillion byte) data scalability, TerraServer was only incidentally a spatial data provider.

The second category consists of spatial data analysis and visualization tools available over the Internet. These offer full-blown distributed mapping capabilities rather than mapping solutions. Two developments are noteworthy: GIS companies positioning themselves to offer Web enabling of GIS, and further integration of GIS/Web/visualization technology (Cook *et al*. 1997) and database cross-linking (Carr *et al*. 1998). The latter extends the early and highly innovative work of Monmonier, who first applied the concepts of geographic brushing in cartography.

Changes are rapid and extremely competitive in the commercial sector, where six-month upgrade cycles are common. I will refrain, therefore, from reciting specifics because these developments are no longer "history" but contemporary and ongoing development. It is apparent, though, that spatial technologies are continuing to converge.

Implications of Distributed Mapping

"Web maps last for minutes rather than years . . ."

1. Transience. A critical difference between Web maps and print maps is their historical legacy: Web maps last for minutes rather than years, whereas the print maps in archives are most certainly more numerous than the Web maps in existence at any given time. Further research is needed into how many print and virtual maps exist, who has access to them, and how they are used. Yet, if we distinguish between the map and a mapping environment (as I think is necessary), then it is likely that far more people potentially have access to mapping environments than to print maps. Equally apparent is a shift from the map as a product to the mapping environment as a process.

This transience has several implications. First, because historical archives do not capture the range of contemporary mapping activities, there is a danger that many mapping practices will not be recorded. Certainly, librarians, and others are keenly aware of this issue. Second, transience raises the issue of what can and should be recorded. Should the maps themselves be archived, or merely the queries used to generate them? After all, MapQuest generates millions of maps per day, but they are fairly similar. Perhaps what should be recorded is the scale, region, and database query, not the map.

2. Cartographer/User Convergence. Accompanying these sweeping structural and procedural changes in cartography in transition is a declining need for "the cartographer" as an expert mapmaker. Although specialists might never disappear entirely (should they?), distributed mapping is eroding the traditional distinction between cartographer and map user. Clearly historians of cartography need to trace the nature and extent of this transition, as well as the forms and intensity of whatever resistance has arisen or might arise.

". . . distributed mapping is eroding the traditional distinction between cartographer and map user."

3. Map Use and Cognition. In 1999, in recognition of new map use environments fostered by distributed mapping, the International Cartographic Association (ICA) reorganized the Commission on Map Use as the Commission on Maps and the Internet. Although users could always interact with maps, interactivity is now defined as an environment in which the display changes in response to user input, usually very rapidly (<1 second response time). This is a real change, which raises many conceptual and research issues, including user interface studies (Torguson 1997), cognition, and the distinction in geographic visualization (GVis) between high and low interactivity. Among the many research topics that warrant attention is the question of navigation within so-called data landscapes. Are interactive, 3D environments more efficacious in learning new environments? How does immersibility affect spatial cognition? And do map metaphors work well in visualizing abstract data, as when a news organization depicts news stories as topographic maps, with local peaks (popular news stories) and valleys (less well-covered news stories).

"One of many cognitive research topics is the question of navigation within so-called data landscapes."

4. Commercial Applications. Distributed mapping seems likely to replicate the history of GIS, which developed in academic geography but is now centered in commercial applications. Clearly the vast majority of Web maps exist not as ends in themselves but to support electronic commerce. As examples, the typical Web map is provided free in hope that the viewer will notice the accompanying advertising, and many of these free maps are closely tied to the travel and tourism business, which is forecast to comprise 35 percent of Web sales by 2002.

CONCLUDING REMARKS

In this paper, I have examined in a preliminary way the history of a particular mapping practice. Drawing on the work of Edney, Harley, and other historians of cartography, I have argued for a non-progressivist history, which not only emphasizes contingencies, delays and dead ends but rejects the reductionist map communication model. I suggest that the history of distributed mapping marks a significant break in (rather than a continuation of) traditional cartography. This discontinuity raises several fundamental questions. What model of representation is most appropriate? A model that considers all spatial data necessarily interoperable and thus amenable to standard definitions and data structures? And thus a model unable easily to accommodate nonstandard spatial data such as local knowledges and spatial cognitions? If so, the history of distributed mapping might simply perpetuate the atheoretical progressivist perspective by treating cartography as an ever-increasingly accurate database with a new name.

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