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Boundary objects and the social construction of GIS technology

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Abstract. The social construction of geographical information system (GIS) technology requires two-way relationships between technology and people. GIS technology, like any other technology, is more than a tool; it connects different social groups in the construction of new localized social arrangements. We examine several instances of how GIS technology involves social negotiation by using a construct of boundary objects developed in a social constructivist framework. Much like geographic boundaries, boundary objects separate different social groups at the same time that they delineate important points of reference between them. Boundary objects stabilize relationships through the negotiation of flexible and dynamic coherences. The negotiation of differences between different groups is fundamental to the construction of GIS technology. Social-constructivist theories and the concept of boundary objects open new ways to understand the relationships between technology and people. We illustrate the application of boundary object theory through studies of the use of GIS data standards and the definition of wetlands.

1 What is local about the construction of GIS technology?

On the basis of broad readings in the science, technology, and society (STS) field (Barnes, 1974; Callon, 1989a; Latour, 1987; Pickering, 1995), we hold that every geographical information system (GIS) is, ultimately, a unique construction resulting from negotiations. Although much of the literature produced by GIS specialists (Dobson, 1983; Goodchild, 1992; Wright et al, 1997) emphasizes a universal toolkit, locally contingent and complex social forces make a different GIS every time. The technological artifacts of each system manifest a social coherence built through negotiations. In the same way, every instance of GIS technology is embedded in an intricate web of social relationships, and remains surrounded by multiple contentions (Curry, 1994; Sheppard, 1995).

The research presented in this paper builds on theoretical insights into the social production of technology known as social constructivism. The social-constructivist perspective presents technology as an integral part of society and its processes of social reproduction. There are various positions on this process (Pickering, 1992). From these positions, we may summarize that the body of social-constructivist case studies and theories provides important insight into the ways in which technology becomes integral to society through the linkage of multiple social worlds.

The part of social-constructivist thinking we specifically mobilize to examine GIS technology is a concept known as boundary objects. This concept articulates the process through which technology becomes part of different social groups, and how technology successfully connects multiple, even opposing, perspectives. Boundary objects provide coherence by linking multiple social groups through the stabilizations of facts and artifacts.

Technology impacts upon all aspects of our life in Western civilization, and the process of constructing boundary objects comes from literature that focuses on a very wide range of technological developments such as the development of the camera (Latour, 1987), the widespread adoption of the safety bicycle (Pinch and Bijker, 1987), the commercially delayed introduction of fluorescent lighting (Bijker, 1992), or the choice of exhibition materials for a museum of vertebrate zoology (Star and Griesemer, 1989). Our understanding of GIS technology is also broad. We consider it to include a wide range of aspects, from choices of coordinate systems and projections, through administrative data-sharing agreements, to mathematical functions developed to describe operations. For this paper we focus on the local negotiation of standards and the positions involved in trying to find conceptual coherence.

Whereas many studies of the relationships between GIS and society cover a macroscale view, this research is distinctly microscale. We hope to show that differences between GIS technologies are to be found in local construction. The studies we present here reveal some of the different ways GIS technology is constructed in complex webs of social relationships.

2 Social groups interact across technological boundaries

One could say that there are as many different GIS as there are social groups involved with GIS technology. Each instance of local negotiation leads to a different and unique GIS technology. This discursive process of finding coherence among competing explanations in science has received much attention in the sociology of science literature. Frequently, these writings refer to a single artifact or the scientist in his or her laboratory (Pickering, 1995). GIS technology is distinctive because the process of construction involves so many social groups. However, we find the basic principles coming from this literature insightful for examining GIS technology. The corpus of work we draw on includes Latour, Pickering, and Woolgar (Akrich and Latour, 1992; Bijker and Law, 1992; Bijker et al, 1987; Callon, 1980; 1989b; 1991; Latour, 1987; 1988; 1993; 1996; Latour and Woolgar, 1979; Pickering, 1992; 1995; Woolgar, 1987). Work on boundary objects, and on the related concept of standardized packages, adds particular insight to the process of developing technology when multiple, highly diverse social groups try to find coherence (Fujimura, 1992; Star and Griesemer, 1989).

This is a broad and developing field, still characterized by formative debates. Although we cannot hope to address all the issues raised in this paper, we want to point out clearly that our work follows what has been called the strong science technology society (STS) argument. Adherents of both the strong and the weak STS arguments maintain that society and technology are linked. Both groups study the impacts of technology and science on society. Both groups find social power relations in the practice of science and the adoption of technology. The difference is in a question of degree. In addition, the strong STS argument holds that technological artifacts are capable of acting in a salient way in society. In a direct sense, technology daily changes our social interactions. Automobiles change where we live, how we shop, how we organize our daily routines, how we pursue our recreation, how we spend our earnings, and so on. The argument has been made that cartography changes how we understand geography (Huggan, 1989). Consciously, and even without our conscious recognition, many forms of technology are intricately interwoven with our lives in many subtle and fundamental ways. People from various backgrounds develop and alter this technology all the time. For instance, one can study how Edison's research changed the social lives of urban dwellers. The questions of implications are interesting, but just as interesting is the work Edison put into constructing the centralized power-providing networks and conglomerates that altered economic development in the 20th century. GIS may not be as universal as electric lighting, but the uses of GIS can have very broad consequences. Studying how people develop GIS technology is crucial to understanding how people connect human places to more abstract concepts of space. Moving in this direction, we introduce a developing body of literature to geography that examines how people are directly involved in the construction of GIS technology.

Before describing the theories behind boundary objects and our methodology, we need to present some of the fundamental theories and concepts from STS that we rely on. As mentioned before, we draw on literature from the French sociologist Latour, Callon and Akrich. Latour and others demonstrate that science and technology are constructed from a multiplicity of viewpoints through the negotiation of principles, concepts, and artifacts that connect multiple social groups. Their work includes a broad reconsideration of the relationships between science and technology. Far more than being just the application of scientific discoveries, technology reinforces ways of seeing the world and thus strengthens the underlying framework for science and technology. In accordance with this understanding of scientific development, GIS technology did not arise from the ashes following a revolution in the scientific paradigmata of geography and require a total change of world view, as would be expected from Kuhn's model of scientific ideas (Kuhn, 1962/1970). As evidence, consider how 'automated geography' has not unfolded exactly as its progenitors hoped (Dobson, 1983; 1993). Instead, GIS has continued many of the most central methods and tenets of the contributing disciplines, dressed now in the theories of the day (Harvey, 1997). Some GIS practitioners from a disciplinary home in geography connect their work to such luminaries as Hartshorne, Hettner, and even von Humboldt. Others trained in landscape architecture connect to Olmsted and Steinitz. To some extent, each group looks in the pond to see their own reflection, ignoring the view from another location. Meanwhile, the growing stream of adopters spread out far away from the original ponds of disciplinary discourse. Multiple social groups interact in the process of developing a complex technology such as GIS. In short, GIS technology should not be taken as a sharp break in the conceptual framework of a discipline, but tightly connected to a larger set of social, economic, and cultural processes.

In this sense, Latour argues that it is increasingly difficult to separate technology from science. This argument surely applies to the tight enmeshing of GIS and geography (and the other related disciplines). Each implementation of GIS technology is a unique combination of technological, scientific, and social perspectives. Social constructivist approaches provide a theoretical framework for examining and understanding these linkages. In reconceptualizing relations between the social and the technological, this approach identifies the importance of a diverse set of actors in the development of technological artifacts such as refrigerators, fluorescent lights, etc, through intended and unintended actions (Bijker and Law, 1992). Technological artifacts can stabilize as well as destabilize relationships. In all instances, the web of technology and society consists of many complex relationships between artifacts and people, institutions and engineers, laboratories and researchers.

According to Latour, technological artifacts occupy a special role in social activities. Technological artifacts often go hand in hand with sweeping changes, just as Pasteur's method of pasteurization required extensive modifications to farming practices. The practices of science are extended into other social words, which leads to a renegotiation and orientation of existing practices (Latour, 1987). Pasteur, for example, extended the spotless hygienic model of his laboratories to the farmers' manure-filled barns. The breadth of these changes had great impacts on the multiple social groups involved: the farmers, dairies, stores, and customers. Technological change is also social change.

Although not by any means the only, or the most important, voice of this academic community, we have found Latour's empirically grounded analysis to be most coherent and exhaustive in this consideration of the interwoven nature of science, technology, and society. His study of the production of science through an analysis of networks of 'inscriptions' serves as the basis for a much broader critical review of the social construction of science (Latour, 1987). His study of Pasteur's construction of a scientific empire with global consequences via the microbe illuminates in exemplary fashion the social role of science (Latour, 1988). The analysis of 'Aramis', an individualized light-rail concept for Paris which failed, shows the tight linkage between science, technology, and politics (Latour, 1992). Also, his theoretical work in rethinking the connections between technology and society presents thoughtful arguments for reconsidering our implicit understanding about technology on the basis of scientist and those affected (Latour, 1993). Instead, Latour proposes a symmetry between society on one side and technology with science on the other. In networks of humans and artifacts, things can have powerful and lasting effects: "... we live in communities whose social bond comes from objects fabricated in laboratories. Ideas have been replaced by practices, apodictic reasoning by a controlled doxa, and universal agreement by groups of colleagues" (Latour, 1993, page 21). The consequences of this theoretization would bear a much deeper reflection than is possible here. As outlined here, we will apply Latour's theory to our study of GIS technology through the concept of boundary objects.

The concept of boundary objects is closely related to Latour's work, but its theoretical origins are more diverse, and its conceptualizations vary to a degree. In the cases we examine, boundary objects offer a concept to unravel some of the complex GIS technology web by focusing on how technology relates various social groups, their institutional mandates, and their disciplinary perspectives. What Latour shows in his analysis of Pasteur's empire building is that Pasteur linked very heterogeneous interests through a series of translations. The participation, and also the enrollment, in this enterprise involved more than the people in the hygiene movement (who supported his work), more than the publicists (who unabashedly supported his work), and more than progressive scientists (who legitimated his findings). Crucial to the success of Pasteur's program is the support of microbes, sheep, cows, and machines, all of which translate between multiple participants (Latour, 1988). Pasteur eventually became unassailable by placing people and equipment in contact with the 'natural world' so that the experiments demonstrated his control over disease. Boundary objects are the artifacts that link these diverse interests.

All work that employs boundary objects follows a central tenet that the mediation of diverse social interests occurs in and during the construction of technology (Neumann and Star, 1996; Star, 1995; Star and Griesemer, 1989). Negotiations lead to translations and stabilization as boundary objects between social groups build coherence. This coherence comes through the stabilization of concepts and artifacts. Boundary objects mediate between different groups; they do not provide a common understanding, or consensus between participants. Instead, they serve a dual function similar to that of geographic boundaries; at the same time as they serve to distinguish differences, they also supply common points of reference. A key difference is the dynamics. Whereas geographic boundaries seem over time to become relatively solid anchors for social relationships between groups, technological boundary objects remain subject to change.

Various authors from other fields propose concepts and offer insights that support the contention that society and technology are connected, and even inseparable. King and Kraemer (1993), writing about data wars, specifically refer to the role of models and technology in contention between agencies. This is more than a matter of choosing which computer or software package will be used. It is crucial, and necessary, that the concepts and assumptions that underlie various groups' models become the focus of debate. Furthering this analysis, Schwarz (a political scientist) and Thompson (a sociologist) analyze the crucial role that technology plays in decisionmaking (Schwarz and Thompson, 1990). They specifically argue that technological decisionmaking involves the engineering of artifacts. Different social groups engaged in decisionmaking aim to establish consensus, but if they fail to create consensus, they strive for some kind of closure (Schwarz and Thompson, 1990). This closure involves the identification of boundaries manifest in the technological artifacts that the social groups construct. Although various debates about the role of technology characterize political science and sociology, these authors provide evidence for the further consideration of boundary objects as an approach to study the complex relationships involving people and technology.

In accordance with Latour, Star, Fujimura, and others, the role of boundary objects can be summarized as the stabilization of certain relationships between participants. When multiple social worlds attempt to find some form of agreement either for collaborative action or in response to outside demands that require a concerted response, they negotiate a social arrangement which encompasses technological elements. This constructed arrangement provides coherence for multiple participants and plays out various forms of power relations. The arrangement simultaneously includes some groups and excludes others. In this sense, coherency means that the position is acceptable, but does not presume complete agreement. "Boundary objects are objects which are plastic enough to adapt to local needs and the constraints of several parties employing them, yet robust enough to maintain a common identity across sites" (Star and Griesemer, 1989, page 393). Boundary objects moderate differences and establish a shared understanding that not only enables (partial) agreement across ontological and epistemological boundaries but also leads to the creation of 'things' with increased validity to a much larger portion of society. For example, these things can be terminals, desks, mapping categories, technical standards, and institutional or social arrangements.

Institutions and disciplines play a crucial role in formulating boundary objects which allow for stable translations between different perspectives of the same phenomenon. In accordance with Latour, boundary objects form crucial intersections and translations between different social worlds. They ensure reliability and simultaneously retain disciplinary, institutional, and social integrity. "Boundary objects facilitate the multiple transactions needed ... to engineer agreements among multiple social worlds" (Fujimura, 1992, page 172). In Fujimura's example of cancer as a boundary object, the physician and molecular biologist can simultaneously refer to a patient's cancer, but at the same time also understand the cancer in completely different ways. In GIS technology there are a multitude of examples. Every time a data-sharing arrangement is sealed, some kinds of boundary objects are involved. These could be physical structures, concepts, standardized approaches. The layers in the multipurpose land information system (MPLIS) cadastre come to mind as an example for boundary objects: each agency populates a layer that remains in their jurisdiction, but is tied together through a common coordinate system to other groups (see figure 1, over).

GIS technology presents a cornucopia of boundary objects, although the structural role seems most essential to multiparticipant GIS. Any time in which negotiations lead to the stabilization of GIS technology, this involves boundary objects. As GIS technology carries the values from multiple social groups, there is hardly any part of a local GIS that is not in some sense a boundary object. This mirrors the pervasive nature of technology in the world, and each person's intimate reliance on technology.

GIS exemplifies these relationships and how they are contested. Not merely an instrument or toolbox, each particular GIS presents a unique collection of artifacts that enable multiple social groups, with divergent or even contradictory values, to mediate these differences and construct more technological artifacts. This is a dynamic process of social production, characterized by differences and contention, that repeats again and

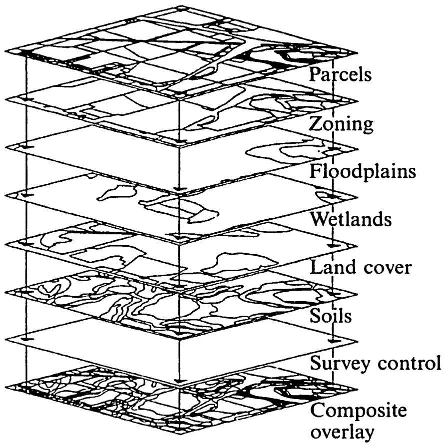

Figure 1. Concept for a multipurpose land information system. Data layers for Section 22, town of Westport, Wisconsin created by six different agencies at three distinct levels of government. Noncopyright work created by Chrisman and Sullivan, University of Wisconsin–Madison, 1984.

again through the construction of boundary objects. Multiple groups can share, and multiple groups can be excluded. At best, the social construction of technological objects is stable for only a specific moment and subject to constant renegotiation. The construction of any technology takes place in a distinct localized environment which strongly constrains how actors interact with each other and the artifacts they construct. Boundary objects are as limited as the social groups participating in their construction.

3 Contentious terms

The negotiation of differences between disciplines and institutions with entrenched perspectives on the world and their mandate can be quite difficult. In geographic information technology we find incidents of this especially in the negotiation of data sharing agreements (Onsrud and Rushton, 1995). A very contentious category in GIS is, for example, wetlands (Shapiro, 1995). This category means different things to different agencies and individuals, yet the generally accepted term 'wetlands' also refers to a locally contingent shared understanding.

In this section we examine some boundary objects which connect different groups that strive towards a common standard for wetlands in the US federal government. Because of the political sensitivity of this issue and the involvement of many federal agencies, we will restrict attention to the primary actors in recent activity. After President Bush stated his administration was adopting a policy of 'no net loss', wetlands have remained a fundamental environmental policy issue. Wetlands, taken alone, or by the 535 members of Congress on the Federal Geographic Data Committee (FGDC) Wetlands Subcommittee's mailing list, is a term everybody somehow agrees to. But at the core of any debate lies the question "What exactly is a wetland?" For this reason we will focus on the contentions surrounding attempts to proclaim a wetland classification scheme, the Cowardin system developed by the US Fish and Wildlife Service (FWS) twenty years ago (Cowardin et al, 1979), as a 'standard' for use by the US federal government (a process completed in 1997).

Through their role in coordinating the Wetlands Subcommittee of the FGDC, staff of the US FWS have led the effort to create a classification standard, a common framework for defining wetlands, via institutional agreements and scientific consensus.

Each attempt to delineate wetlands revisits all the compromises made earlier and thus the definitions vary.

At least 6 agencies are involved in wetlands mapping activities through over 19 programs and projects (FWS, 1990). The agencies include the FWS, Geological Service (USGS), National Oceanic and Atmospheric Administration (NOAA), Natural Resources Conservation Service (NRCS), and Corps of Engineers. The programs range from activities required for hazardous waste clean-ups (Superfund), inventories of estuaries, and flood control, to various regional – federal – state cooperative programs with multiple goals. As President Clinton's executive order leading to the organization of the FGDC pointed out, it is necessary to improve the coordination of these various activities.

Wetlands have been the subject of much FGDC activity. The Wetlands Subcommittee of the FGDC formed a special working group to look into data coordination. This followed a specific Clinton policy goal to reconcile and integrate all federal agency wetlands inventory activities (Shapiro, 1995). A peculiar outcome of these activities is the comparisons of different wetland mapping for an area in Maryland (Wicomico County, the name by which the report is often referred to). With the agenda to reconcile and integrate, this report comes to the conclusion that the four data sets compared "disagree in more than 90 percent of the area that at least one of the four data sets delineates as wetland" (Shapiro, 1995, page xiii). The report cites various reasons for this extreme disagreement, but acknowledges that even if the areas were extended by 50 m in every direction (buffered in GIS) the disagreement is still 60%. The maps included in the report demonstrate that the social agreement on the definitions does not result in actually delineating the same areas on the landscape. The agreement is only paper-thin. The boundary object serves to solve jurisdictional and administrative battles while it conceals continued geographic ambiguity.

These disagreements between the four wetland databases are not merely a result of varying spatial accuracies. The different inventory techniques involved are based on different purposes, procedures, sources, definitions, and logic. For example, each agency's purpose delimits which methods are acceptable for fulfilling their mandate. Flood protection planning obviously needs to consider different criteria than those considered for assessments of estuarine productivity. The geographic boundaries of these different wetlands delineate administrative elements in the environment. In this sense, the wetland boundaries reflect boundary objects. The boundary object 'wetlands' indicates the disciplinary and institutional boundaries of different groups.

Parallel to this analysis, we witness the attempt to standardize wetlands definitions and classifications by using the FWS Cowardin Classification Methods (Cowardin et al, 1979). This attempt was met with contention, particularly from the Corps of Engineers, who were apparently not consulted by the FDGC. The Corps of Engineers developed another methodology and found substantial differences to the wetlands delineated by the Cowardin classification, primarily because of the ecosystems orientation and delineation of wetlands when only one positive wetland indicator is present for any parameter (vegetation, soils, and hydrology). The guidelines used by the Corps of Engineers require all three parameters (Federal Geographic Data Committee and Wetlands Subcommittee, 1997).

The Cowardin classification and wetlands delineation approach are boundary objects. The new standard is used 'extensively' according to its proponents and a wide network of supporters (see the WetNet at http://www.wetlands.ca/index.html for links) including Ducks Unlimited and many other private and public organizations throughout North America. The Cowardin classification becomes a linkage in the relationships between these groups as they produce, use, and distribute wetland data based on the Cowardin classification. This linkage expands the number of groups and increases the integration of heterogeneous groups behind this standard. As an important link in the activities of these groups who enroll in supporting this standard, it connects a wide-ranging, highly diverse set of groups. It becomes part of the communication between these groups. Knowledge of the Cowardin system means to be part of this network, to know certain techniques, certain people, certain instruments well suited for data collection, and certain software developed or optimized for data collection and interpretation. These are its crucial functions as a boundary object.

A boundary object connects the enrolled groups while excluding the opposition. For dissenters, such as the Corps of Engineers, the Cowardin classification is simply not a standard. As the proponents from the FWS are forced to acknowledge, the Cowardin system does not supersede existing law or agency policy and, most importantly, "Application of the standard is not regulatory" (Federal Geographic Data Committee & Wetlands Subcommittee, 1997). This concedes that the Corps of Engineers has an equally stable legal and administrative basis for their more strict definition. Many civilian federal agencies agreed to join the FWS, but the Corps of Engineers can effectively disagree with this program because it is part of the military and therefore not subject to FGDC regulations.

Boundary objects are scientific and technological integrators and separators at the same time. They include some groups and artifacts and exclude others. This is very clear in the example of the Cowardin Wetland Classification System. Boundary objects provide translations between multiple groups. Different institutions and disciplines use wetlands for many purposes, from administering land-use regulation to studying riparian degradation. Some groups focus on water, others on vegetation, even others on wildlife habitat criteria. Each may understand that the others use the wetlands database differently, but they all join in the common social agenda of wetland preservation. As a basic element of a social agreement, the boundary object 'Cowardin Wetland Classification System' facilitates the engagement of multiple groups in furthering the standardization of wetland mapping and inventory activities.

4 Technical standards as boundary objects

In the preceding section we presented some of the difficulties in adoption of standards. Even if the FGDC refers to a 'standard', the resulting document may actually be a standard only for the groups who embrace the approach. In this section we look at the locally contingent adaptation of an accepted standard.

In recent years, technical standardization has become a growth industry for GIS. As soon as the US Spatial Data Transfer Standard (SDTS) was adopted (the culmination of twelve arduous years), competing standards were adopted inside the US military, and international groups began the process of defining standards all over again. For some people, technical standards are overtly hegemonic. They certainly project a unifying influence, but the realities of practice are much more complex. Technological standards have as much a social impact as the technical role more commonly expected. One example of the role of technical standards as a boundary object comes from Germany, specifically the use of the ATKIS standard database model.

In its original conception, ATKIS, an abbreviation standing for Automated Topographic and Cartographic Information System, was intended to be the basic standard in Germany for data exchange. It defines the basic model used for conceptualizing and representing geographic phenomena used by all states in the Federal Republic of Germany. Some states (such as Nordrhein–Westfalen) have even legislated its use at all levels of government; it has become an integral part of any governmental GIS.

One of the crucial problems facing its adoption and use was the inability to finalize one of its core modules. In the original design ATKIS consisted of two parts, a digital landscape model (DLM) and a digital cartographic model (DKM) (see figure 2). The DLM is a catalog of objects that encompass all features on standard 1:25 000 map sheets and some additional objects. The DLM can be extended as required. The DKM should provide the cartographic routines and tools for all map production work by using information stored in the DLM. The landscape model was completed in 1989, but the DKM has largely been abandoned (Harbeck, 1995). Because state surveying departments supply all vector data in ATKIS format, the standardized interface (EDBS) of ATKIS has become a necessary part of any public government's GIS software. Establishment as a standard was additionally supported by the widespread availability of free software. The software (ALK/ATKIS-GIAP) used in Kreis Osnabrück is a further development by a private consulting company (AED-Graphics in Bonn), a spin-off of the original developer, the largest surveying directorate in Germany (Nordrhein–Westfalen). In an exercise of circularity, this agency led the institutional process that adopted ATKIS as a standard. The private–public partnership and legislation in Nordrhein–Westfalen provided substantial momentum for its market introduction and guaranteed adoption by several thousand communities.

ATKIS became a standard, but although it was assured wide-scale adoption, the lack of the digital cartographic model meant it was hollow. Because the basic software was free, basic data for government planning and management were available in this format, the object catalog could be extended to fulfill local requirements, and the software worked, it became the accepted norm for government planning (Junius et al, 1996). The ability to be extended to suit local concerns served to attract more adopters, but this weakened its ability to standardize fully.

Although it is called a standard, ATKIS plays a different role. It is, however, certainly a boundary object that facilitates administrative coordination. Through ATKIS, multiple agencies can be joined into one, more centralistic, administration. ATKIS, only half a technical standard, ends up playing a crucial role in stabilizing relationships and reorganizing power.

Without the cartographic model (DKM), each particular implementation of ATKIS is a specific solution developed by local governmental agencies and software houses. ATKIS was promised in the 1970s as a completely automated solution for mapping. Most institutions gave up on the DKM, and have found their own ways to create cartographic products that come close to replicating their pen and ink antecedents. Each construction has a unique combination of data modeling and cartographic

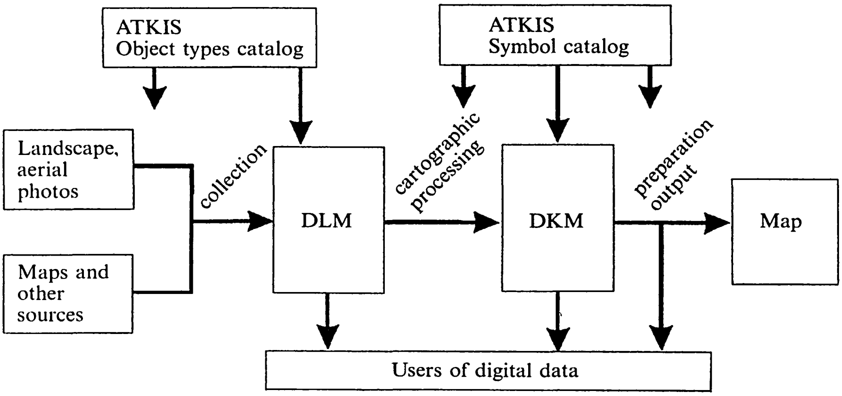

Figure 2. The automated topographic cartographic information system (ATKIS) consisting of a digital landscape model (DLM) and a digital cartographic model (DKM). Based on Harbeck (1995).

symbolization together with attributes and software. Although ATKIS aids the consolidation of administrative activities within local government, sharing of ATKIS GIS data between different implementations is astonishingly difficult.

As a boundary object for local administrators, each locally constructed version of ATKIS essentially excludes outsiders from sharing this data. Because each implementation of ATKIS has unique ways of coding cartographic attributes instead of the missing DKM, the standardized interface EDBS essentially works only for the exchange of data between the same software and hardware implementation. Each ATKIS-GIS is the particular result of different social worlds which construct GIS technology. In Kreis Osnabrück, the county executive led the construction of more centralized GIS technology by placing control of the GIS in a new group under his direction, which was not affiliated with any agency. Data can be shared with agencies, counties, etc, who use the same software, but not, for instance, with the city of Osnabrück's planning agency.

As a boundary object in a hierarchical public administration with legislated control of state and communal mapping activities, ATKIS structures relationships and delimits organizational power to the groups who constructed the technology. It follows that ATKIS is more pertinent as a local framework than as a technical standard for state-supported GIS activities. Still, even as a weak standard, it uses GIS technology as the means for establishing and negotiating boundary objects. Having a data standard is of little use if different software leads to incompatibility between agencies. Thus, the geodesist's office of each state combined ATKIS (the public standard) with a public or private software package for their jurisdiction. The local governments dependent on these state services usually followed the lead, though each could include and exclude elements. The resulting geography of GIS solutions mirrors the power to specify technology, and creates a geography of the potentials for collaboration on infrastructure and planning.

According to Wolfgang Göpfert (personal communication, 1996), the situation in Osnabrück is typical for anyone trying to work with ATKIS data from different states. Each state must employ teams of experts to resolve the 'never-ending differences' between ATKIS implementations. Each local construction includes some and excludes others. Clearly, ATKIS, and, more generally, all instances of GIS technology, are more than a tool. In multiple ways, for multiple social groups, GIS technology consists of the technological artifacts that instrumentalize institutional and disciplinary power through boundary objects.

5 Conclusion

Just as Pasteur's 'science' constituted new relationships between people and technology, for the farmers, dairies, stores, and consumers, geographic information technology involves the construction of new networks of relationships. Each of the cases above demonstrates the complex web in which GIS technology is constructed. The contention surrounding GIS technology is inseparable from this web. Boundary objects aid in deepening our understanding of GIS technology by focusing on the interwoven relationships between people and technology. By examining the construction of technology in a web of social relations as a project to establish coherence instead of coercion or consensus, GIS technology is clearly localized. The Cowardin system encounters resistance, but acceptance as a standard comes through enrollment in a web of relationships that is not unanimous and varies locally. ATKIS never really makes it as a technical standard for German local administrations. Instead it ends up as a framework for shifting power relationships and localized construction of a GIS. Local administrators use ATKIS to facilitate organizational change. Use of their implementation means becoming part of a particular set of relationships. Even when conceived of as a hegemonic technical standard, GIS technology ends up a distinctly local construction.

Boundary objects, as technological artifacts, function at multiple levels. A GIS is, at one level of analysis, a boundary object that consists of other boundary objects. Literature values on soil moisture may be boundary objects for various schools of thought in environmental sciences and are subject to negotiation through ongoing scientific debate. These same literature values can also serve to construct the technological artifacts that relate the heterogeneous social worlds of policy specialists, institutions, and concerned citizens in the negotiation of acceptable risk. ATKIS is a catalog of negotiated objects that represent geographic phenomena, and it is the means of regulating access to public resources. Each instance of GIS technology exists as part of an intricate web of social relations.

GIS technology and technoscience are not monolithic autonomous edifices but the localized results of processes of negotiation that involve the construction of artifacts to fit various social perspectives. Socially acceptable and equitable decisions rest on technological boundary objects which delineate social arrangements and construct the artifacts that embody multiple values. More than tools to make better decisions with, GIS technological artifacts are the boundary objects which reinforce social agreements about human geography. The contentions surrounding GIS technology revolve around its construction by existing social groups, as part of ongoing institutional and disciplinary processes. The localized involvement of artifacts, groups, and people are the actual crux of contention.

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