GIS Best Practices

Essays on Geography and GIS: Volume 3

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What Is GIS?

Making decisions based on geography is basic to human thinking. Where shall we go, what will it be like, and what shall we do when we get there are applied to the simple event of going to the store or to the major event of launching a bathysphere into the ocean's depths. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet. A geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions.

GIS organizes geographic data so that a person reading a map can select data necessary for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a basemap of real-world locations. For example, a social analyst might use the basemap of Eugene, Oregon, and select datasets from the U.S. Census Bureau to add data layers to a map that shows residents' education levels, ages, and employment status. With an ability to combine a variety of datasets in an infinite number of ways, GIS is a useful tool for nearly every field of knowledge from archaeology to zoology.

A good GIS program is able to process geographic data from a variety of sources and integrate it into a map project. Many countries have an abundance of geographic data for analysis, and governments often make GIS datasets publicly available. Map file databases often come included with GIS packages; others can be obtained from both commercial vendors and government agencies. Some data is gathered in the field by global positioning units that attach a location coordinate (latitude and longitude) to a feature such as a pump station.

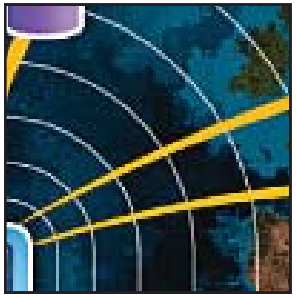
GIS maps are interactive. On the computer screen, map users can scan a GIS map in any direction, zoom in or out, and change the nature of the information contained in the map. They can choose whether to see the roads, how many roads to see, and how roads should be depicted. Then they can select what other items they wish to view alongside these roads such as storm drains, gas lines, rare plants, or hospitals. Some GIS programs are designed to perform sophisticated calculations for tracking storms or predicting erosion patterns. GIS applications can be embedded into common activities such as verifying an address.

From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of planet Earth.

Geospatial Responses to Disasters: The Role of Cyberspace

By Melinda Laituri, Warner College of Natural Resources

The geospatial community can meet the challenge of disaster management. The Haitian earthquake, the Indonesian tsunami, Hurricane Katrina, the World Trade Center, Chernobyl, California wildfires, Danube flooding, Three Mile Island—multiple, large-scale disastrous events continually occur, and the magnitude and frequency of disasters appear to be increasing.



Disasters represent the intersection of human communities with natural events where the built environment may actually exacerbate the outcomes of these events as in the case of Hurricane Katrina. Other disasters are the result of human activities and conflict that impact local communities with long-term and far-reaching outcomes as in the case of Chernobyl and the World Trade Center tragedy. Extreme events impact both the industrialized and developing worlds. However, the results of disasters are felt disproportionately in low-income countries where population growth, inadequate infrastructure, environmental degradation, and poverty create conditions of vulnerability. Disasters become "teaching moments" to better understand the human relationship to the natural world (through events such as earthquakes, tsunamis, and volcanic eruptions) and how the constructed environment of cities, rerouted rivers, and overgrown forests aggravate extreme events.

Disasters reveal the need for integrated solutions that include on-the-ground emergency response informed by geospatial technologies and digital databases. Visualization and spatial applications are critical in pre-, during, and in postdisaster management and response. Increasingly, cyberspace plays a role in geospatial responses to disaster in the following ways: (1) revealing the role of virtual communities in disseminating information via new and innovative means (e.g., mobile phones, mashups, crowdsourcing); (2) illuminating the need for interdisciplinary approaches to address disasters where geospatial approaches and technologies are at the forefront; (3) identifying efforts to improve communication through spatial data; and (4) developing long-term strategies for recovery efforts, risk reduction, restoration, and monitoring programs.

Steven Johnson's book entitled *The Ghost Map: The Story of London's Most Terrifying Epidemic and How It Changed Science, Cities, and the Modern World* (published by Riverhead Books in 2006) recounts the story of John Snow's map of cholera deaths in 1854. Johnson emphasizes the role of local knowledge and multidisciplinary approaches in creating a bird's-eye view of the spread of the disease from a central water pump in industrializing London. Once scientific opinion accepted the waterborne theory of cholera, Snow's map became an important demonstration of the integration of science and local knowledge, linking an artifact of the built environment to a pattern of disease and disaster. In 1883, Krakatoa, a Pacific island, vanished in a volcanic eruption. Simon Winchester recounts the disastrous aftermath of this event in *Krakatoa: The Day the World Exploded: August 27, 1883* (published by Perennial in 2003). This was one of the first events to have nearly instantaneous global coverage due to the technology of the time: telegraphy, underwater cables, and news agencies. This sharing of knowledge of place and disaster is one of the main characteristics of the *global village*. Marshall McLuhan coined this phrase in 1960, referring to the contraction of the world due to electronic media.

Disasters bring us closer via the Internet (the underwater cables of the Krakatoa era) and the World Wide Web (telegraphy and news agencies). Online disaster communities, made up of the victims and their families, governments, news outlets, nongovernmental organizations, humanitarian aid groups, and an interested public, form in response to cataclysmic events. The online disaster community is global in that it transcends national boundaries in virtual space; solicits aid and intervention; and provides multiple lines of communication and information dissemination via chat rooms, blogs, and help lines. Virtual scales are not measured in terms of distance but by one's relationship to the event: friend, family, disaster responder, aid provider, or government official. However, the disaster occurs in an explicit geographic location with measurable results that are photographed, recorded, and placed online—where the physical environment intersects with virtual space.

Effective disaster management and response demand rapid utilization of information and data from many sources. The ability to seamlessly integrate and distribute digital data into spatially explicit forms for rapid assessment and analysis during and after a disaster remains a challenging undertaking. Specialized data, data networks, and information processing methods and technologies are needed in a highly dynamic situation fraught with uncertainty and unpredictability. However, during and post-disaster activities reveal high levels of access to and pooling and sharing of digital resources, skills, and capabilities through the creation of novel and innovative sociotechnological networks.

Researchers have done considerable work in addressing the role of geospatial technologies in disaster response and management. This research includes GIS and public safety; GIScience; and applications for emergency response, disaster recovery networks, vulnerability mapping, and local responses to disaster using GIS. The integration of the Internet with GIS applications has been applied to such areas as 3D real-time emergency response, serving maps on the Internet for emergency escape routes, and mobile GIS and digital video for urban disaster management. Geospatial modeling has been used for such things as determining evacuation routes, tracking hurricanes, and ascertaining refugee populations. The conceptual basis for disaster prediction and planning is undergoing a shift as evidenced by Susan Cutter et al. in a 2008 paper entitled "A Place-Based Model for Understanding Community Resilience to Natural Disasters." Cutter et al. highlight the need to focus on resilience and adaptability rather than risk and vulnerability. The January 2010 *Cartography and Geographic Information Science* is a special issue that focuses on temporal and spatial scales of hazards and disasters, monitoring of long-term recovery, and methods to improve communicating knowledge of these events using spatial data. A suite of research has considered the role of local communities in integrating local knowledge into disaster management activities. The notion of "people as sensors"—people collecting information, often spatial information, to aid in the recovery process and posting this information on the Internet for broad dissemination outside the established traditional channels of emergency response—is yet another aspect of the intersection of disaster, place, and technology.

In 2007, the National Research Council (NRC) published *Successful Response Starts with a Map: Improving Geospatial Support for Disaster Management*, written by the Mapping Science Committee. This report describes the state of the art of geospatial data and tools for emergency management and emphasizes the need for improvement on how this data and the tools are used. Mechanisms to increase data sharing, use of satellite images, and Internet services for data provision are among the critical needs to enhance the use of geospatial technologies. The Indonesian tsunami and Hurricane Katrina reveal important advances that occurred via the use of the Internet and GIS. For example, the disaster of the Indonesian tsunami demonstrated the ability to quickly provide remotely sensed images both before and after the event that showed the extent of damage. This occurred through partnerships between software vendors, Internet service providers, and remote-sensing companies. The failure of governmental agencies in the aftermath of Hurricane Katrina resulted in numerous individuals responding via creating maps of donation and emergency aid sites. Creating data-sharing mechanisms in times of emergency response is needed; however, the report cites security as one of the main reasons for the lack of data sharing and for failure in providing data for emergency response. The recommendation by the Mapping Science Committee is to strengthen the National Spatial Data Infrastructure (NSDI) of standard development and clearinghouse construction and to provide the framework for emergency management data needs and coordination.

In 2009, the United Nations Foundation and Vodafone published a report, *New Technologies in Emergencies and Conflicts: The Role of Information and Social Networks*, that describes the new technologies and innovative uses of existing technologies to address crises. The mobile phone; the growth of broadband; and emerging telecommunications, computing, and multimedia are having a profound impact on how, when, and where people communicate. One of the observations reported is the shift to "many to many" forms of communication, such as social networking, from the traditional "one to many" type of communication in the form of radio and television. These communication changes will impact dissemination and delivery of information, as well as develop people-centered approaches focusing on local needs and emergency planning efforts. Geospatial trends are viewed as either top down, where high-resolution satellite images are used to assess infrastructure damage after disasters, or bottom up, where crowdsourcing techniques integrate cell phone broadcasting, social networking, and online maps to pinpoint local crisis conditions.

When disasters have occurred, there has been an informal development of technology and communication that has self-organized during the event to provide coherent, relevant information outside the traditional information providers. The spontaneous response to disaster was particularly acute after Hurricane Katrina in the United States, coupled with Internet and mobile applications outside the traditional structure of information dissemination and emergency management. These events reinforce emergency management as a community activity that is local yet linked to national-level priorities. However, the issues of appropriate data protocols and validity and authentication of information are not insignificant. Collaboration and coordination between government agencies, humanitarian organizations, and private companies remain problematic due to conflicting missions, data security issues, and inadequate funding of emergency response technologies. There is an international need for a regulatory framework for geospatial tools and communication techniques similar to the call by the NRC for the NSDI.

The integration of mapping, Global Positioning Systems, satellite imagery, and interactive geographic information systems provides important opportunities for developing and sharing information and techniques. "Technological gift giving" during disaster events has resulted in special licensing arrangements, innovative data sharing, and new applications. Mashups—the mixing of hybrid Web applications from multiple sources—combine satellite imagery with maps and geospatial data to provide local data. This activity capitalizes on researchers' observations about the need for data collection at finer spatial scales, such as neighborhoods and subneighborhoods, to create better disaster management plans. Disasters create space for the establishment of new networks, opportunities for collaboration, and information exchange.

Maps and, increasingly, satellite images are ubiquitous throughout the online disaster landscape. Global and regional consortiums provide technical advice about disaster response, training opportunities for GIS disaster applications, direct access to satellite imagery, technical help in processing digital data, and links to other information portals. Often, the latest satellite images and maps of a recent disaster can be found on these sites. For example, United Nations Institute for Training and Research (UNITAR) Operational Satellite Applications Programme (UNOSAT) provides the international community with geographic information and aims to universalize access to satellite imagery. The Radio and Internet for the Communication of Hydro-meteorological Information for Rural Development (RANET) project uses Internet technology to disseminate early warning information, satellite imagery, weather, and climate data to rural areas. The application of appropriate or best-fit technologies is a critical aspect of GIS and Internet applications due to factors such as bandwidth, literacy levels, and data availability. Cell phone and wireless technology are key factors in countries with inadequate wired infrastructure where interactive maps can be accessed on cell phone screens.

In 2005, Paul Currion wrote about the "first responders of the wired world" in reference to the innovative uses of blogs, message boards, pinpoint maps, mashups, and Web portals by technically savvy Internet users to share local information about disasters. While emergencies vary widely in scale, severity, and duration, they are inherently local. Oftentimes, information required from a GIS for immediate emergency response is seemingly simple, not requiring complex analytic procedures but reliable and adequate data. These activities attempt to distribute appropriate, accurate information in a timely fashion and, in some instances, in real time. Multiple disasters have facilitated the formation of volunteer organizations that provide hands-on expertise to develop location-specific GIS applications. These organizations respond to disaster events by developing a list of volunteers and soliciting assistance in response to disasters. For example, GISCorps coordinates short-term, volunteer GIS services to underprivileged communities worldwide. Immediately after the Haitian earthquake, MapAction had a team on the ground to assist in relief coordination through developing maps of relief deliveries.

We have learned several important lessons in novel uses of satellite imagery, GIS, and Internet technology in translating disaster information to other audiences:

- The Internet enhances the ability for interactive communication of relevant information quickly and efficiently, provided people have the means to access the technology.
- Different forms of media interact to fuel news stories and information dissemination. The Internet, online media, and blogs work in concert, remixing and amplifying information.
- Synergistic effects from multiple new technologies (mobile phones) are enhancing access to information, as well as how information is disseminated.
- Web sites, wikis, interactive maps, and blogs offer immediate assistance to a community, such as relief efforts, locations of impacted areas, potential dangers, shelter locations, donations, and ways to assist.
- Different types of information can be made rapidly available that depict the geographic extent of the event, and satellite images provide a bird's-eye view of the location.
- People living around the world have the opportunity to learn about the human tragedy that results from a disaster, and this fosters a sense of global community.

These lessons suggest a promising future based on a strong technological imperative. However, several challenges exist:

- Accessibility to a reliable computer network and Internet connections is dependent on an overall well-developed infrastructure.
- Issues related to data availability and access to copyrighted and classified data are evident in both developing and developed countries.
- The power of information and communication technologies is at times not evidenced by their actual performance during a catastrophe. For example, during the Kashmir earthquake of 2005, basic GIS data layers were not available, and processed satellite images revealed little in the way of damage assessments.
- Maps and information needed for the local scale are often not available. This data is location specific, sensitive to scale, and rarely has adequate coverage of the social landscape.
- Information assessment for disaster management must be closely examined to determine if such databases and GIS products are really meeting the needs of the impacted populations.

- Information must be authentic and valid to be trusted by the users and affected populations.

There are several actions that the geospatial community can take to address issues associated with disasters. These include

- Develop standards and protocols for data for emergency management, building on the framework of the NSDI.
- Increase the skills in information systems for emergency managers and humanitarian aid workers to better understand the role of data collection and information for emergency management.
- Develop training for community-based emergency data collection for localities. Develop drills for emergency response that include GIS applications, rapid response assessments, and analysis.
- Develop new methods for geovisualization.
- Develop emergency management GIS applications and curricula to train the next generation of emergency responders. Develop geospatial educational tools for multirisk assessment.
- Build participatory partnerships and approaches in mapping disaster events.
- Research and develop appropriate temporal and spatial scales for disaster management databases.
- Establish long-term monitoring data collection programs to understand recovery and restoration in an interdisciplinary environment.
- Integrate the lessons learned to create feedback mechanisms for improving response to disasters.

Solutions have been implemented that include technological innovation and creative public-private partnerships. However, solutions must go beyond technology and tools and address long-term, foundational change through interdisciplinary approaches and long-term strategies building on the innate creativity of individuals. In 1997, Susan Hanson edited *10 Geographic Ideas that Changed the World* (published by Rutgers University Press), which discusses three ideas that directly relate to the issues of disaster management. The "idea of the map" is arguably the most powerful of geographic ideas in its ability to convey information authoritatively. Coupled with digital technology, the map takes on new forms through the use of "geospatial technologies," broadening our perspective by creating the possibility of analyzing ever larger amounts of geographic data. Situating the interactive map within the context of "human adjustment and adaptation" heralded the emergence of analyzing coupled human and natural systems. We now find ourselves at the crossroads of the virtual and physical worlds where solutions to disaster management provide an important role for geography and geospatial tools.

About the Author

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Governance of the NSDI

By Will Craig, President of the National States Geographic Information Council

The concept of the National Spatial Data Infrastructure (NSDI) has been around since the early 1990s, and the name has been in existence since 1994, when President Bill Clinton used it to label his executive order creating it. The name sounded strange when I first heard it; why *infrastructure*? Then I realized that *data is infrastructure*. Everybody else got it too. It was the first time the United States began to see data as infrastructure—equivalent to concrete roadways and metal pipes. This was the new information age, and data was the basis for economic growth and environmental integrity.

It was a wonderful concept—liberating and energizing—but we have gotten much less than I was hoping for over the past 15 years. There are only a few success stories. As I see the problem, we simply have not organized ourselves very effectively. This article describes the current geospatial governance structure in the United States, discusses current problems, looks at state models for success, and makes recommendations for doing things differently at the national level.

Through a directive from the Office of Management and Budget (OMB), we have put significant effort into identifying key data elements in that infrastructure and assigning responsibilities to develop and maintain that data. The Federal Geographic Data Committee (FGDC) is charged with coordinating those efforts but does not have the power to make or enforce rules. Federal agencies continue to create "stovepipes of excellence" and cooperate only when desirable to themselves, very rarely because of outside pressure. Equally important, the NSDI has a federal focus and often does not meet the needs of state or local government—let alone the private sector or public.

State governments have done a better job of coordinating their state spatial data infrastructures. Ironically, they have gotten funding from FGDC to develop the strategic and business plans necessary to make the transition. Many states have geographic information officers (GIOs) to coordinate state-level activities and advisory councils composed of other stakeholders to help coordinate the activities of municipal, county, and tribal governments. A similar approach should be used at the federal and national level to create the governance structure that will allow us to finally reach the full potential of the NSDI.

Cracks in the system are becoming apparent to Congress. In June 2009, the Congressional Research Service published a report called *Geospatial Information and Geographic Information Systems (GIS): Current Issues and Future Challenges*. The report tries to address the questions of "how effectively [is] the FGDC . . . fulfilling its mission" and "how well is the federal government coordinating with the state and local entities" (see fas.org/sgp/crs/misc/R40625.pdf).

On July 23, 2009, the Energy and Mineral Resources Subcommittee of the House Natural Resources Committee held an oversight hearing on federal geospatial data management. Rep. John Sarbanes of Maryland quoted a U.S. General Accounting Office (GAO) report from his briefing material saying that only 4 of the 17 [sic] FGDC member agencies were in compliance. A video of that hearing and written testimony of witnesses is online at resourcescommittee.house.gov/index.php?option=com_jcalpro&Itemid=27&extmode=view&extid=278. Most of the discussion in the hearing was about eliminating redundant data collection. Not much was about filling gaps.

OMB, FGDC, and NSDI

The current federal geographic governance structure has a long history. In 1953, the federal executive OMB issued Circular A-16. Originally aimed at federal surveying and mapping activities, that circular has been revised several times and is now titled *Coordination of Geographic Information and Related Spatial Data Activities*. Circular A-16 is the basis for all federal geospatial data coordination efforts. OMB is a cabinet-level office, monitoring the performance of the various federal agencies that report to the president, guiding them when they stray, and making recommendations for future presidential budgets. This is a powerful office, but it has tended to delegate geospatial data coordination to FGDC.

FGDC was created in the 1990 revision to OMB Circular A-16. This is when the circular began looking at spatial data use and coordination across federal agencies. The committee consists of leaders from 30 federal agencies—up from 18 listed in the 2002 revision of Circular A-16. It is chaired by the secretary of the interior. The strength of the committee is determined by the strength of personalities running it, and that strength has varied over the years. Not all member agencies are fully committed, as indicated at the oversight hearing.

When the NSDI was created in 1994 by President Clinton's Executive Order 12906, its purpose was to "support public and private applications of geospatial data in such areas as transportation, community development, agriculture, emergency response, environmental management, and information technology." Responsibility for implementation was given to FGDC. With minor modifications to provide a special role for the new Department of Homeland Security, President George W. Bush continued the NSDI in his Executive Order 13286 in 2003.

There were weaknesses in all this. One of the things that went wrong fairly early was a fixation on *framework data*. These were the seven data layers that were seen as first steps toward fulfilling the vision of the NSDI: geodetic control, orthoimagery, elevation and bathymetry, transportation, hydrography, cadastral, and governmental units. Circular A-16 describes these as the seven "themes of geospatial data that are used by most GIS applications." In fact, I most frequently use land-use and soil data for my environmental work and socioeconomic data for my urban planning work. But, these seven were seen both as easy first steps and as a solid frame to which other data could be referenced. To be sure, Circular A-16 lists some 34 data categories and assigns each to a federal agency, but few agencies are working on their assignments. Land use is not in the list of data categories—along with many other elements that we all find useful in our daily work.

It turned out that framework data was not so easy to complete or coordinate. The National Academy of Sciences points out that the Federal Emergency Management Agency (FEMA) needs land surface elevation data that is about 10 times more accurate than data currently available (2007) for most of the nation. The transportation layer is maintained in various forms by agencies including the U.S. Census Bureau and Department of Transportation, the latter having several different versions. The cadastral layer effort soon abandoned securing data on all private landownership and even smaller federal land holdings, leaving only large federal holdings, like Yellowstone National Park, and Public Land Survey corners.

One of the best success stories is GPS, something that was not seen as part of the NSDI. This technology was developed by a federal agency (the U.S. military), but kept relatively secret with only degraded access to it until 2000 when President Clinton opened the door for public access. Today, GPS is a multibillion-dollar industry with devices on the dashboards of cars, in cell phones, and even on dog collars. This happened within a single agency and outside our national data governance structure.

We knew early on that data could not be developed without a partnership between the federal government on the one hand and state, local, and tribal governments on the other. Those relationships were required in Clinton's NSDI executive order. They were underscored in a series of reports from the National Academy of Sciences. The first of these was *Toward a Coordinated Spatial Data Infrastructure for the Nation*, which predated Clinton's executive order and set the stage for it. Perhaps the most relevant today is the 2003 report, *Weaving a National Map: Review of the U.S. Geological Survey Concept of* The National Map, that envisioned a national quilt of high-resolution local data that could be rewoven into a national blanket of uniform quality.

Data for the Nation

The National States Geographic Information Council (NSGIC) and others are starting to use the phrase *for the nation*. Imagery for the Nation (IFTN), Transportation for the Nation (TFTN), and Elevation for the Nation are examples of this new approach in labeling. To NSGIC, this term means something quite specific: data is available nationwide, it has sufficient spatial and topical resolution to meet the needs of all levels of government, and resources are available to keep the data current. The processes for conceiving, developing, and maintaining such data are described with 20 discrete criteria on the NSGIC Web site. Only a few data themes exist that meet these criteria.

There are four ways to produce data that meets the needs of all levels of government. The traditional way is for federal programs to deliver data at sufficiently fine resolution to meet everyone's needs. A good example of such a program is the Soil Survey Geographic Database (SSURGO) county soils maps provided by the Natural Resources Conservation Service; these maps provide sufficient detail for state and local applications, though not for individual farmers who want to manage their fields intensively. Also, the Census Bureau provides population and housing data at the block level and above—again, sufficient for all but the most detailed local needs. The National Wetland Inventory and the National Hydrography Dataset also fall into this category. Not many other examples exist. I call these "happy accidents." They almost always involve a federal partnership with state or local government, but those partnerships are matters of convenience and not the result of our governance structure.

A second way to meet the needs of all levels of government is through federal programs that allow state and local governments to participate through buy-up options. The IFTN program, proposed by NSGIC, starts with the U.S. Department of Agriculture's (USDA) 1-meter National Agricultural Imagery Program and allows locals to add sensors (e.g., four-band) and expanded coverage into nonagricultural areas. IFTN also provides for the business needs of local government with a higher-resolution 1-foot program that would be administered by the United States Geological Survey (USGS). This component also has buy-up options that include 6-inch resolution, true orthophotographs; increased horizontal accuracies; and other features important to local government. Ideally, states would coordinate the many local requirements and funding, making it easier for USDA, USGS, and their contractors to meet local needs.

A third way to meet the needs of all levels of government is for local government to collect data that meets its needs, with state and federal governments rolling this data up to summary levels sufficient for their more general needs. This is actually fairly rare, but I have a good example from McLeod County in central Minnesota. The county wanted 1-foot contour data and worked with several local cities and a watershed district to contract for services. USGS needed only 10-foot resolution for its National Elevation Database, but contributed financially so it could access the finer data, process it, and publish a 10-foot summary of the original county data. The Minnesota Department of Transportation also contributed to the effort. This partnership was recognized in 2008 with a commendation from the governor of the state of Minnesota.

A fourth approach is for the private sector to get involved and create something that has value to the nation—enough value to support the enterprise. A number of popular Web providers of maps, travel directions, and aerial photos are doing a great job of delivering this kind of information to the public; much of the data comes from government sources, but it is delivered in useful packages by private firms. Ideally, we would base other work on public/private partnerships, so government has a say in the nature and availability of the final product. We lack good models on how this should work, but the potential is there.

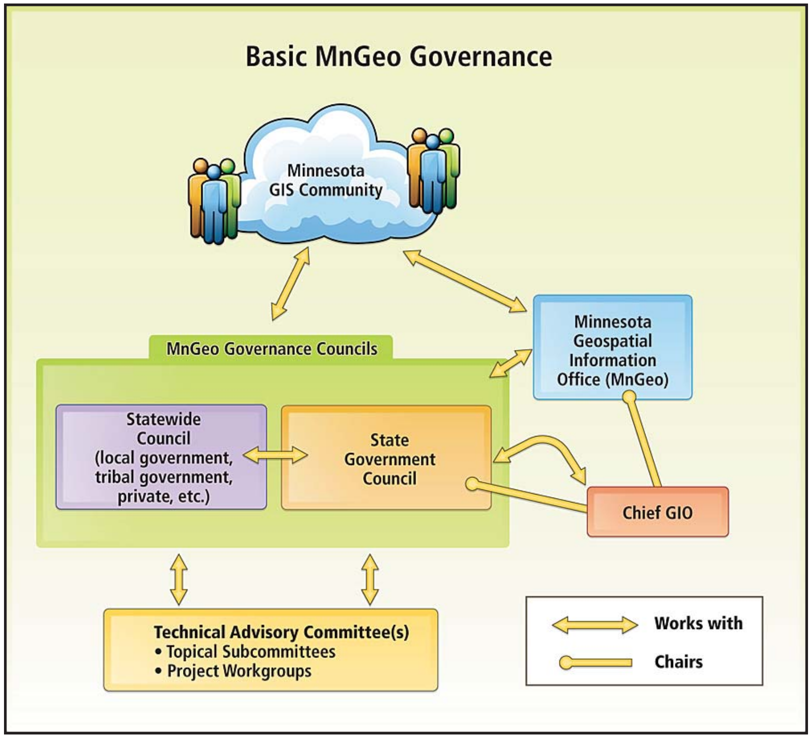
Parcels and Addresses

Parcels and addresses are especially useful pieces of the NSDI from my perspective. They present a conundrum for federal partnerships. Many federal agencies need such data for their day-to-day operations or in emergencies. This data is typically created and maintained by local government, but there is no systematic way for this local data to flow up to state or federal agencies as described in the third option above for delivering data for the nation. There is no system for collecting and organizing local data, so federal agencies collect their own data. Taxpayers foot the bill for multiple versions of the same data. No governing body in Washington has responsibility for resolving the conundrum—addressing the fragmented landscape.

Data on addresses is the most vexing because it is the closest to being ready for widespread sharing. The Census Bureau and the U.S. Postal Service have nationwide databases but share only with each other. A 1982 Supreme Court decision supports the Census Bureau decision to not share its Master Address File with local government. That decision was based on the court's understanding of congressional intent in writing Title 13 of the U.S. Code forbidding access to internal Census Bureau records, not on any intrinsic right of privacy. The past 27 years have brought significant developments in technology and business databases, making moot decisions about unknown addresses.

Most recently, the Census Bureau has spent millions of dollars hiring out GPS work to add an x,y coordinate to every front door in America. For some reason, this information is also held as nonpublic. I could easily see a system where I provide my address to the Census Bureau and it returns my x,y coordinate. Local governments and 911 authorities would love to have this information for their business needs but do not have the funds to collect this data themselves and cannot get it from the Census Bureau. I am not talking about internal and possibly illegal housing units, just about the front door that anyone could see when walking by. I am not talking about unknown places in the woods, only those buildings for which the local authority already has addresses. The x,y coordinates remain an internal, nonpublic resource at the Census Bureau, paid for with public funds, but not available to the public or any other government agency. Does this make sense?

Parcels are in a similar situation, but different because no federal agency has responsibility for maintaining a national parcel dataset. Nearly every domestic agency, save USGS, has the need for parcel data. USDA needs parcel data to manage its crop insurance programs. Our national parks and forests need information on parcels to communicate with neighboring landowners. FEMA needs parcel data for rescue and recovery operations; it wasted millions of dollars following Hurricane Katrina in aid to people who did not own property in the damaged area. The Census Bureau could use parcels on the outer edge of cities to update their governmental unit boundaries. The U.S. Department of Housing and Urban Development (HUD) could use parcel data to monitor urban decay or renaissance. Some would argue that access to good parcel data would have allowed us to foresee the recent mortgage crisis and intervene before things went so horribly wrong.



A 2007 report by the National Academy of Sciences looked at parcel data issues: *National Land Parcel Data: A Vision for the Future.* I was on the committee that drafted that report. We envisioned a Web mapping service that would allow people to see parcel maps, along with a limited set of attributes, for any place in the country without regard to county or state borders. States would play an intermediary role, adding their own landownership data and managing records for those local governments without sufficient internal capacity. This is technically and economically feasible. Yet the United States cannot do it because we lack the will and a governance structure to develop and manage such a system. The first recommendation of our study was to create a panel to identify a national coordinator to begin working on the governance issue. The Bureau of Land Management (BLM) has responsibility for the cadastre under OMB Circular A-16, so the panel would start by determining whether BLM has enough authority and capacity to do the job. Two years after our report was published, there is still no panel looking at this issue.

States Are Organized

States around the country coordinate GIS activities better than the federal government. They typically have some kind of statewide council. The most effective councils coordinate activities at the state level with a strong hand but work gently with local governments. They include representatives from all stakeholder groups, including federal, state, county, municipal, and tribal governments; private-sector GIS users and providers; the academic sector; nonprofit organizations; utilities; and the general public. They have clear vision, supported by a strategic plan and a business plan.

The Fifty States Initiative was designed by NSGIC and FGDC to help states become effective coordinators. This initiative is intended to connect with the data resources of the 50 states and, through them, to the 3,141 counties, over 18,000 municipalities, and more than 370 tribal governments. To this end, FGDC has funded 46 states in developing strategic and/or business plans to support the NSDI.

NSGIC has developed a scorecard so each state can know how it stands on relevant criteria. The scorecard has nine criteria starting with a full-time coordinator and sustainable funding. More powerful criteria include a clearly defined authority for state-level coordination, the ability to coordinate with local government and other stakeholders, and a formal relationship with the state chief information officer (CIO).

My own state recently created the Minnesota Geographic Information Office (MnGeo). The state had been struggling with fragmented operations, and its NSGIC scorecard showed it. With a grant from FGDC, it hired a private firm to help bring together stakeholders and develop a governance model that would work *(see diagram above)*. The plan called for the new MnGeo with two advisory bodies: one for *state government* coordination and one for *statewide* coordination. The state government advisory council is composed entirely of state agency GIS representatives. The statewide advisory council is composed of representatives of local government, the private sector, tribal government, nonprofit organizations, and academia. The GIO participates on both committees—as the chair of the state government council and as a nonvoting member of the statewide council.

The National Solution

The simple solution is to "get organized," along the lines of what the states are doing. There are no technical problems in developing the NSDI, only organizational ones. Increased governance is necessary to make things work better. I see four parts to this new model: (1) creation of a new federal Geographic Information Office, (2) a radical empowerment of FGDC to coordinate federal GIS activities, (3) the creation of a new body representing nonfederal stakeholders, and (4) development of a congressional oversight committee to watch and guide overall activities.

At the federal level, we need a structure that supports and demands coordination of geospatial data development across federal agencies. This should start with the creation of a new position—a federal GIO. The office should be part of the Office of Management and Budget. OMB develops and executes a government-wide management agenda and assists the president in preparing his budget. It already houses the new federal CIO. This is the ideal place to set federal mandates for agency operations.

One of the first tasks of the new GIO should be to develop an economic argument for the NSDI. NSGIC has estimated the price of the NSDI at nearly $9 billion, with an annualized cost of about $2.5 billion. Is it worth it? If so, where are the highest payoffs? The effort should begin by defining a rigorous methodology that delivers results understandable to both economists and the educated public, including agency heads and members of Congress. The study should cover all levels of government, the private sector, and the public. NSGIC has suggested that the economic study should be delivered within 18 months after the GIO takes office. If the study shows positive benefits, support for the NSDI will logically follow.

FGDC should continue to coordinate activities at the federal level, but with more muscle behind its efforts. Duplicative activities should be identified and corrected. Agencies should be held accountable for fulfilling data assignments. Gaps should be identified, prioritized on economic return, and assigned to agencies. To operate effectively, FGDC probably needs to be moved from its current home in the Department of the Interior to OMB, since that organization has the mandate to review the performance of federal agencies and make budget recommendations affecting them.

Over time, I have written two contradictory articles about what it takes to make a difference in the world of sharing data. In 1995, I wrote about institutional inertia and the need for a body outside the organization, usually the chief executive or legislative body, to set the rules for organizational mandates and individual rewards. Later, in 2005, I recanted, as I recognized the value of "white knights" who are motivated to do what is right regardless of the institutional rules. I think I was right the first time—at least for something as large and complex as the NSDI. Certainly, large federal agencies need that outside oversight.

A National Spatial Data Council (NSDC) is needed to coordinate nonfederal activities. This idea has been around for years. I took this name from a 1998 report of the National Academy of Public Administration, *Geographic Information for the 21st Century.* The NSDC, or whatever we decide to call it, should be composed of stakeholder representatives from state, local, and tribal governments; the private sector; academia; and others. The representation should look much like that of the current National Geospatial Advisory Committee to FGDC, but would have power, grant-making ability, and access to the GIO. The federal government should be represented by FGDC as a nonvoting member.

A new congressional oversight committee could do three things: set the expectations for federal agencies and the new NSDC; monitor performance, asking hard questions; and become the political champion to support the development and maintenance of the NSDI.

As a nation, we have gone nearly two decades with limited progress on the NSDI. Most of that progress has been made through the goodwill and volunteer efforts of altruistic people and organizations. We are in the information age, but we're still building stovepipes. It's time to put some muscle and money behind the NSDI vision.

About the Author

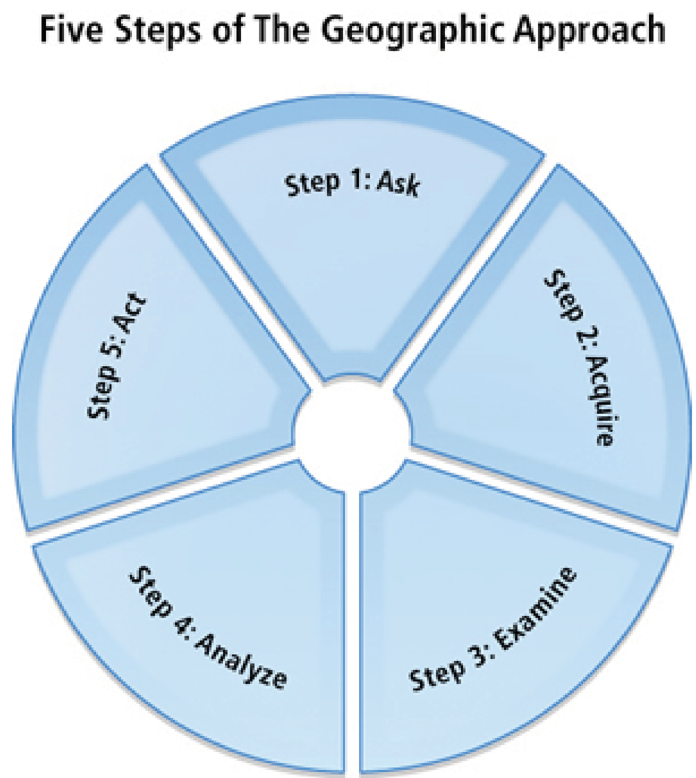
Will Craig is associate director of the Center for Urban & Regional Affairs at the University of Minnesota. He chaired URISA's Research Agenda Group in the mid-1980s, proposing an agenda that had a strong focus on institutional research. He is the president of NSGIC and has been inducted into URISA's GIS Hall of Fame.

(Reprinted from the Fall 2009 issue of *ArcNews* magazine)

What Is The Geographic Approach?

By Matt Artz and Jim Baumann, Esri

Perhaps you've heard Esri president Jack Dangermond mention The Geographic Approach. It's a phrase he often uses to describe his high-level vision for using geospatial technology as a key method in finding answers to problems.



The Geographic Approach provides the necessary framework for GIS analysis.

"Geography, the science of our world, coupled with GIS is helping us [better] understand the earth and apply geographic knowledge to a host of human activities," Dangermond says. "The outcome is the emergence of The Geographic Approach—a new way of thinking and problem solving that integrates geographic information into how we understand and manage our planet. This approach allows us to *create* geographic knowledge by measuring the earth, organizing this data, and analyzing and modeling various processes and their relationships. The Geographic Approach also allows us to *apply* this knowledge to the way we design, plan, and change our world."

Solving problems using a geographic approach is not new. It is fundamental to the way geographers study and analyze our world. The concept is perhaps best articulated by Ian L. McHarg in the 1969 book *Design with Nature*, in which he details the philosophical context for managing human activities within natural and cultural landscapes.

As a methodology, The Geographic Approach is used for location-based analysis and decision making. GIS professionals typically employ it to examine selected geographic datasets in detail, which are combined for the comprehensive study and analysis of spatial problems. This methodology parallels the well-known scientific method and includes a research-focused, iterative process for examining diverse datasets and uncovering potential solutions. GIS augments the analytic process, helping give people a clearer understanding of complex problems that often include geographic components. This in turn allows better decision making and more opportunities to conserve limited resources, as well as improves the way we work. Many experienced GIS professionals intuitively begin their projects with a structured methodology of this nature. But for those new to GIS technology, these five steps will provide a defined and proven approach.

Step 1: Ask

Approaching a problem geographically involves framing the question from a location-based perspective. What is the problem you are trying to solve or analyze, and where is it located? Being as specific as possible about the question you're trying to answer will help you with the later stages of The Geographic Approach, when you're faced with deciding how to structure the analysis, which analytic methods to use, and how to present the results to the target audience.

Step 2: Acquire

After clearly defining the problem, it is necessary to determine the data needed to complete your analysis and ascertain where that data can be found or generated. The type of data and the geographic scope of your project will help direct your methods of collecting data and conducting the analysis. If the method of analysis requires detailed and/or high-level information, it may be necessary to create or calculate the new data. Creating new data may simply mean calculating new values in the data table or obtaining new map layers or attributes but may also require geoprocessing. Sometimes you might have to consider using *surrogate measures,* which allows data creation through indirect means. For example, an economic indicator can be used as a surrogate for income. However, because of the limits in collecting accurate data in this way, it is necessary to indicate in your results the manner in which the data was collected.

Step 3: Examine

You will not know for certain whether the data you have acquired is appropriate for your study until you thoroughly examine it. This includes visual inspection, as well as investigating how the data is organized (its schema), how well the data corresponds to other datasets and the rules of the physical world (its topology), and the story of where the data came from (its metadata). Since the data ultimately selected for your analysis depends on your original question or questions, as well as the results that you are seeking and how those results will be used, your examination may be dependent on how precise the data must be to answer the original questions. Because data acquisition can be the most expensive and time-consuming part of the process, it is important that you begin with a well-defined data model for your organization and your project. This will provide the basis for evaluating potential data acquisitions.

Esri President Jack Dangermond says that the Geographic Approach is a new way of thinking and problem solving.

Step 4: Analyze

The data is processed and analyzed based on the method of examination or analysis you choose, which is dependent on the results you hope to achieve. Understanding the effects of parameters you have established for the analysis, as well as the algorithms being implemented, is critical so that you can correctly interpret the results. Do not underestimate the power of "eyeballing" the data. Looking at the results can help you decide whether the information is valid or useful, or whether you should rerun the analysis using different parameters or even a different method. GIS modeling tools make it relatively easy to make these changes and create new output.

Step 5: Act

The results and presentation of the analysis are important parts of The Geographic Approach. The results can be shared through reports, maps, tables, and charts and delivered in printed form or digitally over a network or on the Web. You need to decide on the best means for presenting your analysis. You can compare the results from different analyses and see which method presents the information most accurately. And you can tailor the results for different audiences. For example, one audience might require a conventional report that summarizes the analyses and conveys recommendations or comparable alternatives. Another audience may need an interactive format that allows them to ask what-if questions or pursue additional analysis. Yet another audience may simply need to know how the results affect them or their interests.

The Geographic Approach provides the necessary framework for GIS analysis and helps ensure accurate, verifiable results. By carefully documenting, archiving, and sharing your results and methodology, other researchers receive the opportunity to verify your findings. This practice, called *full disclosure*, also allows statistical measures of the reliability of this data to be established.

Clearer Understanding of Results

Using a methodology such as The Geographic Approach formalizes the analytic process with GIS, which allows a clearer understanding of the results and promotes a response that can be supported by the data. By applying The Geographic Approach to help us solve complex problems, we can make better decisions, conserve resources, and improve the way we work.

(Reprinted from the Fall 2009 issue of *ArcNews* Online)

Kingston University London: 20 Years of GIS Education

By Kenneth Field, Course Director, Kingston Centre for GIS

In the United Kingdom, Kingston University London (KUL) holds a special place in the history of academic programmes in geographic information systems. In 1989, Kingston was the first higher education institution (HEI) in the world to design and offer a three-year bachelor's degree wholly in GIS. September 2009 marked 20 years of the course as it comes of age and welcomes its 21st intake.

With more than 650 graduates of the bachelor's degree course, 50 master's graduates, and more than 400 students of our distance-learning training course for professional in-service training, as well as successful doctoral candidates, the university has many students who have gone on to develop careers in the geographic information (GI) industry.

At least 10 KUL graduates currently work for Esri, and many students work for data and solutions providers. KUL GIS graduates are in demand by diverse organizations, including environmental agencies; local government; retail, commercial, mapping, transportation, and utilities organizations; and software firms. One of our first master's graduates, Armen Asyran, recently helped compile *Earth*, which is the world's largest atlas published by Millennium House.

KUL has been a world leader in GIS throughout its first 20 years and firmly intends to remain so. Since the initial decision was made in 1988 to establish the first bachelor's degree course and a centre of excellence in GIS, many changes have taken place, but the current faculty is committed to developing interesting, cutting-edge courses, undertaking research and consultancy, and maintaining and developing links to the GI industry to support common goals.

The GIS faculty at KUL has pioneered a number of developments subsequently taken up by the university. Tim Linsey and Ed Parsons were responsible for making online resources available via the Mosaic Web browser in the early 1990s with GISWWW and its own bulletin board. Parsons also built his own local area network within the university for the distribution of GIS resources.

Faculty members are also routinely involved in national-level resource initiatives, such as the development of MasterMap Download, the academic interface for Ordnance Survey's MasterMap data, which faculty helped shape prior to its rollout to all UK universities.

With a strong team of former faculty members and alumni who continue to support KUL, there exists a unique group of academics and professionals who have shaped this major contribution to the development of GIS.

Close liaison with the GIS sector keeps the course current and directly relevant to the needs of employers. Links with suppliers, consultants, bureaus, and a wide range of users have been established, resulting in student visits, internships, and guest lecturers. This collaboration provides crucial support for the course and helps maintain KUL's reputation among employers.

High-quality, externally funded research has characterized the work of the faculty and informed teaching in areas such as remote sensing of hazards and upland forests, spatial statistics and the handling of geographic information, image-based systems, multimedia, and virtual reality development in GIS, as well as the application of GIS to environmental problems. Ongoing is a two-year project to explore use of students' personal technologies for data gathering and sharing and the role of social networking sites, such as Twitter and Facebook, for the creation of collaborative geolearning environments and innovative Twitter maps—which, taken together, I call "cartoblography."

Research, Consultancy, and Commercial Links

Under the consultancy name Kingston Centre for GIS, the faculty has delivered training workshops and seminars at GI industry events for the past 20 years, such as the annual Solutions Centre events at UK GIS conferences. The Kingston Technical workshop series is now delivered at the annual Association for Geographic Information (AGI) GeoCommunity conference. KUL also gets involved in GIS Day by hosting a day of events for local schoolchildren, and plans are under way to take part in the National Geographic Society/Esri GeoMentor scheme. Vanessa Lawrence, CB, Ordnance Survey's CEO and director, is a fellow of KUL and recipient of an honorary doctorate and visits regularly to deliver a keynote lecture that is normally timed to contribute to GIS Day. KUL also supports and encourages growth in GIS courses elsewhere. In 2006, KUL led a major European-funded project to establish a GIS curriculum, course, lab, and staff training at the University of Sarajevo, Bosnia-Herzegovina. KUL also runs an annual GIS summer school in conjunction with AGI.

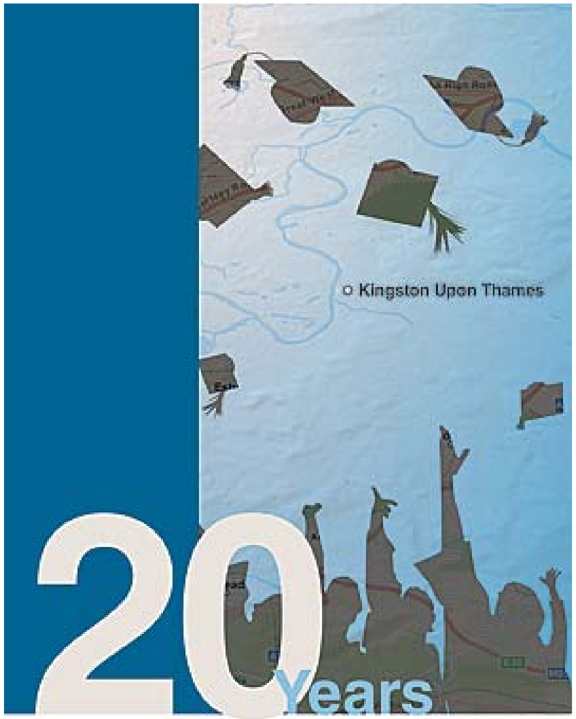
Commercial and academic links feed directly into the course through our innovative Contemporary Issues in GIS invited-speaker series, which has seen a number of illuminating speakers over the years. Faculty members are also in demand by other institutions as advisers, adjunct tutors, and external examiners, such as Penn State's Masters in GIS (James O'Brien), the UNIGIS MSc programme (Nigel Walford), and the Royal School of Military Survey MSc course in defence geographic information (Kenneth Field). Such networks are important to share expertise, disseminate findings and experience, and support healthy inter- and intrasectoral collaboration.

KUL is also supporting ESRI (UK) Ltd. in developing its Enterprise Training Lab based on applications and student projects developed over recent years.

The GIS Road Map at KUL: Another 20 Years and Beyond

The last 20 years have seen phenomenal change and growth in technology, data, software, and the GI industry. KUL has been part of that growth and has led initiatives to keep courses at the forefront of GIS education. As KUL embarks on the next 20 years, there are echoes of 1989 and the drivers that stimulated the initial development of the course.

Perhaps now, more than ever, an increasingly democratized approach to handling spatial data and mapping has caught the public's imagination and illustrated the power of the geographic approach. Ever more jobs and careers require graduates to be highly skilled and trained professionals in GI systems and science. The impact of online data providers and the rapid diffusion of mobile and Internet mapping applications have reignited interest in the combination of geography and technology that should provide a steady supply of students to courses and serve the now maturing discipline well in the future. Many more pivotal positions in GI-related careers will be needed—careers for people who can now gain professional recognition as Chartered Geographers with expertise in the field of GIS (CGeogGIS).



The recent review and events marking the 20th anniversary of the milestone *Chorley Report on Handling Geographic Information* (1987) in Britain (see below) reaffirmed the position of GIS at the heart of spatial data infrastructures. The Infrastructure for Spatial Information in Europe (INSPIRE) initiative promotes data interoperability and sharing of spatial information and provides a framework across Europe. The newly released *Location Strategy for the United Kingdom* (Geographic Information Panel, 2008) puts the nature of place, where events happen and impact the people and assets at that location, at the centre of national, regional, and local initiatives and service delivery. The purpose is to better plan and to manage risk and use resources more efficiently, maximizing the value of geographic information to the public, government, and UK business and industry.

This is a crucial document in shaping the information economy for the coming years and emphasizes the continued need for suitably knowledgeable and well-trained graduates in GI systems and science. In 2008, GIS was officially included as a core component of the school geography curriculum, meaning that every schoolchild will now be formally introduced to GIS. Along with KUL, other universities and ESRI (UK) are making great strides to support development of GIS at the school level, which should see a thriving graduate and postgraduate market emerge.

The Early Years in Kingston upon Thames: From Idea to Inception

In honor of this 20th anniversary, I would now like to reflect on the history of the course and reveal some of the stories that have characterized GIS at Kingston.

Since 1947, the School of Geography at Kingston Polytechnic had developed a strong reputation for its bachelor's degree course in geography. The cartography component had always been a core component of the course, and staff research interests with Ph.D. awards at the time focused on digital cartography and expert systems. Courses in digital cartography; remote sensing; and, in 1986, an option in GIS were introduced into its geography course. Only 250 metres along the road, the Environmental Studies Department of Kingston College of Further Education (KCFE) had been involved with cartography and related subjects since the 1960s. Demand for suitable qualifications in cartography by people working within established cartographic agencies led to the development of two-year part-time Ordinary and Higher National certificates in 1968 and 1970, respectively. These incorporated all aspects of cartographic practice, theory, and production methods, as well as surveying, photogrammetry, mathematics, and geography.

The rapid expansion of digital cartography in the 1980s and development of the new discipline of GIS had a major effect on the education programmes of both institutions. These developments provided the context for the institutions, in the late 1980s, to jointly develop a new range of educational and training courses in GIS that reflected the strong growth of technology in geography during that decade as geographers sought to develop links between increasingly available data and the computer's ability to facilitate effective storage, manipulation, and analysis. A proposed bachelor's degree course in GIS emerged as a collaborative development concerned with spatial data handling and the application of GIS technologies to a wide spectrum of problems and their solutions. The aim of the course was to enable students to acquire knowledge, skills, and expertise in GIS, integrated with mapping technology, for the purposes of spatial data management.

Justification for the world's first degree course in GIS gained support on the basis of an expanding market for GIS specialists identified in two key publications. Both the 1984 *Report on Remote Sensing and Digital Mapping* (House of Lords Select Committee on Science and Technology, 1984) and the 1987 *Report to the Secretary of State for the Environment of the*

Committee of Enquiry into the Handling of Geographic Information, chaired by Lord Chorley, identified the need for degree courses in GIS. The *Chorley Report* particularly stated "it is apparent that there continues to be a serious gap between education and training requirements and actual provision in the geographic handling areas. In our view, this gap is a factor holding back the use of technology for handling spatial data and the shortage of trained personnel could be even more of a constraint in the future as demand increases." The *Chorley Report* concluded that there was "a need to increase substantially, and at all levels, the provision of trained personnel."

Evidence from both the U.S. and UK markets suggested that the rapid expansion of GIS technology would lead to the establishment of whole new GIS-based employment areas, including local government, utilities, commerce (in particular, sales and marketing), and environmental management. The AGI formed as a direct consequence of recommendations in the *Chorley Report* and identified a growth in demand for spatial information, computer systems that utilize this data, and trained personnel who can operate such systems. In the UK, £70M had been spent on GIS technology by the end of 1988, with an annual cost of £30M by the turn of the decade. Many HEIs subsequently incorporated GIS units into existing geography courses, and one-year master's courses began to appear. The appropriateness of the "bolt-on" GIS unit, the problems of what to teach and how to properly resource practical exercises, and the lack of experience within existing staff were all problems that had to be addressed. The need for individuals with multiple skills in underlying subject areas, such as geography, engineering, and business; in conceptual and practical considerations of GIS; and in broader IT and management issues demanded a more substantive educational approach.

At the school level, the inclusion of geography in the national curriculum and the general popularity of the subject was leading to oversubscribed geography degree programmes. The rise in interest in computing and information technology subjects and the increasing role of computers in society also suggested that the development of a new academic course that married these together could provide a popular subject. This potential was supported by the fact that the GIS unit in the geography degree course at KUL was itself oversubscribed.

Market research of 45 leading firms and establishments that had some involvement with GIS found overwhelming support for a bachelor's degree course and a growing need for graduates. Further support and advice on the course design were received from the AGI, British Cartographic Society, British Computer Society, and Ordnance Survey. The survey response was also crucial in the naming of the course, a decision which, with hindsight, was remarkably astute. The course was originally to be titled *Environmental Information Management and Mapping Systems*. On recommendation, the title changed to *Geographical Information Systems*, reflecting a terminology that was to become ubiquitous. With impetus established, a committed group of people in the School of Geography at the Polytechnic, alongside staff from KCFE, prepared course documents in January 1989 that were ratified by the Council for National Academic Awards (CNAA) in June. The first intake of 35 students in September 1989 was impressive for such an innovative course and fully justified its development.

Within two years, there were more than 40 students majoring in GIS, and in 1991, a Higher National Diploma (HND) course in GIS was added to its portfolio, with an intake of 20. In 1992, the Polytechnic was granted permission to become a university, and Kingston University London was born as the first cohort of students graduated with the highest student retention rate in the university, along with the highest level of graduate employment within six months of taking the course. By 1997, there were approximately 70 students per annum studying GIS.

The aim of the bachelor's degree course was to provide students with the skills and understanding necessary to apply GIS technology to a wide range of environments. This provided a framework for understanding GIS concepts and how they are integrated into broader information technology strategies. Objectives were to

- Provide an interdisciplinary and integrated approach to GIS.
- Develop critical and analytic skills for problem solving through the use of GIS.
- Enhance students' ability to undertake effective decision making.
- Develop skills in evaluation, application, and management of information systems.
- Provide a sound understanding of the role of spatial data in decision-making processes.
- Understand the business, social, and environmental implications of GIS.
- Provide students with a range of skills and knowledge to undertake a range of GIS-related jobs.
- Help students adapt to the rapid changes taking place in information technology and be able to respond flexibly and positively.

Course content was organized around four underlying themes. The environmental information theme examined sources and character of social, economic, and physical data operating over various spatial and temporal scales and their measurement and description. Information collection methods covered principles of data collection and capture, photogrammetry, remote sensing, surveying, and social and economic surveys. Data analysis explored GIS and other information systems for data management, intelligent data manipulation, spatial and statistical analysis, and system design and evaluation. Finally, information management and communication focused on cartography and digital mapping, report compilation and desktop publishing, management, and budgeting implications. The course engendered an applied philosophy so students gained knowledge and understanding of the application of GIS to effectively examine and solve spatial questions.

Back to the Now

The general framework survives to this day, though the balance and course content have changed considerably to both reflect developments in GIS and lead curriculum initiatives in the science and delivery of GIS. Core modules in GIS are now delivered to all students of geography, environmental science, geology, and forensic science in Year 1 (approximately 250 students). This reflects the maturation of GIS as a discipline and the enabling role it plays for all geoscience subjects. It also reflects the philosophy of embedding GIS as a framework for study across a range of subjects in the university that extends to landscape architecture, computing, business, and surveying. Modules in photogrammetry and topographic techniques have long gone but have been replaced by emerging areas, such as mobile GIS and GeoWeb applications, which keep the course on the cutting edge.

Kingston University London
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www.kingston.ac.uk/centreforgis

The current curriculum introduces GIS across four Year 1 modules: Digital Earth, GIS Techniques, Applications of Geoanalysis, and Fundamental Programming Concepts. In Year 2, modules offered include Digital Mapping, Remote Sensing, Spatial Databases, Geographical Analysis and Modelling, GIS Software Development and Customisation, GIS for Enterprise and Research, and Mobile GIS. The final year promotes specialties in a wide range of options, including geovisualization, GeoWeb applications, crime pattern analysis, GIS and health, GIS and hazards, systems analysis and design, high-definition surveying, and geodemographic analysis. The bachelor's degree course now also has Joint Honours options where students can combine a major in GIS with a minor in computing, Web technologies, business administration, or landscape architecture. This provides tremendous scope for linking GIS with a range of other subjects at KUL.

In 2003, fieldwork was embedded into the programmes to take GIS out of the classroom, and this has since provided a focus for some innovative work in mobile GIS, fast becoming a contemporary area of expertise at KUL. Current curriculum initiatives are focusing on server-based GIS both in class and for mobile GIS and high-definition surveying with terrestrial lidar for data gathering, handling, manipulation, and visualization.

Alongside the bachelor's degree course, KUL has successfully delivered a Continuing Professional Development (CPD) distance-learning training course for professional in-service training since 1994. This is a nonaccredited option that many hundreds of employees have studied part-time in distance-learning mode. Despite preeminence in the provision of a bachelor's degree course, it wasn't until 2002 that KUL added a master's programme to its portfolio. The Masters in Applied GIS combined a major in GIS with a minor in environmental science. In 2008, provision was extended by the addition of a distance-learning Masters in GI Systems and Science. Both programmes are recruiting strongly as GIS becomes ever more pervasive in a wide range of activities that require professionals to retrain and seek professional development and qualifications in GIS.

KUL will continue to support state-of-the-art GIS education and make it available to all those who join the world's first GIS course as it embarks on the next 20 years.

Esri Development Center

KUL is also extremely proud of its recent accreditation as an Esri Development Center (EDC), which provides recognition and special status to university departments that have exemplary programs. Being an EDC site brings a number of benefits, including an annual student of the year award that was conferred for the first time in 2009, suitably commemorating 20 years of the course.

The 20th Anniversary Celebration

To celebrate the 20th anniversary, KUL will be holding a reunion reception for past and present GIS staff, alumni, and current students in 2010. For details of the event, contact Dr. Kenneth Field through the Kingston Centre for GIS Web site (kingston.ac.uk/centreforGIS).

Changing Faces of GIS Faculty, Keeping Pace with Change, and Recognition and Rewards

Many people have contributed to GIS at KUL. Some remain, while some have moved on and made other significant contributions in academia and business, leaving openings where new faculty have taken up the reins. KUL has also benefited from its relationship with a number of major figures in GIS over the years. A substantial financial commitment was made in terms of staffing and computer technology to launch the course. This was vital to success, and resourcing remains a vital aspect of quality course provision. Over the years, the Kingston Centre for GIS has frequently been recognized and honored. Visit esri.com/arcnews/kingston or kingston.ac.uk/centreforGIS for a list of key individuals, important technology, and awards.

Acknowledgments

Many thanks to all those past and present faculty members who contributed to this review. As ever, it's a team effort.

About the Author

Dr. Kenneth Field is course director and principal lecturer at Kingston Centre for GIS, Kingston University London. He has been editor of *The Cartographic Journal* since 2005 and is a member of the Council of the British Cartographic Society. His teaching and research focus areas are cartography and geovisualisation, as well as mobile GIS and mobile mapping.

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Building INSPIRE: The Spatial Data Infrastructure for Europe

By Max Craglia, Joint Research Centre of the European Commission

Disclaimer: The views expressed in this article are the author's alone and do not necessarily represent those of the Joint Research Centre or the European Commission.

This article is about the European spatial data infrastructure (SDI), which is called, formally, Infrastructure for Spatial Information in Europe, or INSPIRE. Many readers of *ArcNews* will be familiar with the concept of an SDI, as efforts in the United States to develop a National SDI (NSDI) have been under way since the mid-1990s (see also "Governance of the NSDI" by Will Craig in the Fall 2009 issue of *ArcNews*), and many other countries in the world are very active in developing their own. For the readers who are not so familiar with the concept of an SDI, it is easier to think of it as an extension of a desktop GIS. Whilst in a "normal" GIS most of the data we geospatial professionals use for analysis is our own or collected by the agency we work for, an SDI is an Internet-based platform that will make it easier for us to search and find data that may be relevant for our work and that may be collected, stored, or published by other organizations and often other countries. The key components of an SDI are, therefore, catalogues of available resources, documented in a structured way through metadata; agreed-upon access policies and standards; and a set of services to access and download the data to our GIS. In many countries, some key datasets have been identified that are perceived to be of general usefulness to many (the so-called "framework" data in the United States). Priority has therefore been given to documenting them and making them available. Once we have found and downloaded the data we need, we analyze it in our GIS, and finally, we contribute (often but not often enough) to the international pool of knowledge by publishing the results of our analysis so that others can use them.

This, of course, is a rather simplistic perspective. SDIs are children of the Internet, without which they would not exist. They are also the response to an increased recognition that the environmental and social phenomena we are called to understand and govern are very complex, and that no single organization has the know-how and the data to do the job alone. Hence, we need to share knowledge and data across multiple organizations in both public and private sectors, and SDIs support this effort.

INSPIRE

The INSPIRE Directive is a legal act (Directive 2007/2/EC) of the Council of the European Union and the European Parliament setting up an Infrastructure for Spatial Information in Europe based on infrastructures for spatial information established and operated by the 27 Member States of the European Union (EU). For the readers not familiar with the institutional setup of the European Union, it is worth pointing out that the EU is not a federal state but a union of 27 sovereign Member States that agree through a series of international treaties (the latest being the Lisbon Treaty of 2009) to the policy areas in which they wish to share responsibilities and resources (e.g., agricultural, environmental, and regional policies) and those that remain instead the exclusive domain of the national governments (e.g., defense and immigration).

The key decision-making bodies are, therefore, the national governments—represented in the Council with a number of votes proportional to the size of the country—and the European

Parliament that is elected by universal suffrage every five years. The European Commission is the civil service body of the EU and has the power of proposing legislation (to the Council and European Parliament) and monitoring its implementation once approved. Not being a federal state also means that there is no equivalent to the U.S. federal agencies in respect to the collection of topographic or demographic data like the United States Geological Survey and the Bureau of the Census. All data comes via the responsible organizations in the Member States. As a result, setting up an EU-wide SDI can only be done in a decentralized way, building on the SDIs and related activities established and maintained by the Member States.

The purpose of INSPIRE is to support environmental policy and overcome major barriers still affecting the availability and accessibility of relevant data. These barriers include

- Inconsistencies in spatial data collection, where spatial data is often missing or incomplete or, alternatively, the same data is collected twice by different organizations
- Lack or incomplete documentation of available spatial data
- Lack of compatibility among spatial datasets that cannot, therefore, be combined with others
- Incompatible SDI initiatives within a Member State that often function only in isolation
- Cultural, institutional, financial, and legal barriers preventing or delaying the sharing of existing spatial data

The key elements of the INSPIRE Directive to overcome these barriers include

- Metadata to describe existing information resources so data can be more easily found and accessed
- Harmonization of key spatial data themes needed to support environmental policies in the European Union
- Agreements on network services and technologies to allow discovery, viewing, and downloading of information resources and access to related services
- Policy agreements on sharing and access, including licensing and charging
- Coordination and monitoring mechanisms

INSPIRE addresses 34 key spatial data themes organized in three groups (or Annexes to the Directive) reflecting different levels of harmonization expected and a staged phasing *(see table 1).*

The legal framework of INSPIRE has two main levels. At the first, there is the INSPIRE Directive itself, which sets the objectives to be achieved and asks the Member States to pass their own national legislation establishing their SDIs. This mechanism of European plus national legislation allows each country to define its own way to achieve the objectives agreed upon, taking into account its own institutional characteristics and history of development. As an example, Germany does not have a single SDI but a coordinated framework with 17 SDIs, one for each of its states (Länder) and one at the federal level (which also means that 17 different legal acts had to be passed to implement INSPIRE). Similarly, Belgium will have probably three SDIs, one for each of its regions (Wallonia and Flanders) and one for Brussels. The INSPIRE Directive also requires the establishment of an EU geoportal operated by the European Commission to which the infrastructures of the Member States have to connect.

The drawback of having 27 different "flavours" of INSPIRE is that making the system work is undoubtedly more difficult. For this reason, the Directive envisages a second level of legislation, more stringent because it has to be implemented as is and does not require follow-up national legislation. In European terminology, this is called a regulation. Therefore, INSPIRE envisages technical implementing rules in the form of regulations for metadata, harmonization of spatial data and services, network services, data and service sharing policies, and monitoring and reporting indicators to evaluate the extent of the Directive's implementation and to assess its impact. Each of these regulations needs the approval of the Member States and the European Parliament. As of January 2010, the regulations for metadata, network services (discovery and view), and monitoring and reporting have already

Annex I
Coordinate reference systems
Geographical grid systems
Geographical names
Administrative units
Addresses
Cadastral parcels
Transport networks
Hydrography
Protected sites
Annex II
Elevation
Land cover
Orthoimagery
Geology
Annex III
Statistical units
Buildings
Soil
Land use
Human health and safety
Utility and governmental services
Environmental monitoring facilities
Production and industrial facilities
Agricultural and aquaculture facilities
Population distribution and demography
Area management/restriction/regulation zones and reporting units
Natural risk zones
Atmospheric conditions
Meteorological geographical features
Oceanographic geographical features
Sea regions
Bio-geographical regions
Habitats and biotopes
Species distribution
Energy resources
Mineral resources

Table 1: Key data themes addressed by INSPIRE.

been approved. Those for data- and service-sharing policy, network services (transformation and download), and the first set of specifications for the harmonization of data have been approved by the representatives of the Member States and are now under the scrutiny of the European Parliament.

INSPIRE has some characteristics that make it particularly challenging. The most obvious is that it is an infrastructure built by 27 different countries using more than 23 languages. The requirements for multilingual services and interoperability among very different information systems and professional and cultural practices are, therefore, very demanding. This means, for example, that existing standards have to be tested in real distributed and multilingual settings. In the best scenario, all works well, but for a European-wide implementation, there is a need to translate the standards and related guidelines into the relevant languages (International Organization for Standardization [ISO]; Open Geospatial Consortium, Inc. [OGC]; and other relevant standards are typically in English only). In other instances, testing has demonstrated that the standards are not mature enough, or leave too much room for different interpretations, and thus require further definition or individual bridges to make different systems interoperate. This can be seen with tests on distributed queries in catalogues all using the same specifications (OGC Catalog Service for the Web 2.0). The tests identified a number of shortcomings that required the development of an adaptor for each catalogue, which in a European-wide system with thousands of catalogues would obviously not scale.

These shortcomings have been put forward to the OGC for consideration (for further details, see inspire.jrc.ec.europa.eu/reports/DistributedCatalogueServices_Report.pdf). In harder cases still, there are no standards available, and, therefore, they have to be created. This applies, for example, to "invoke" services that are needed for service chaining and to the specifications required for the interoperability of spatial datasets and services, which is a central feature of INSPIRE. To understand the context, it is worth reminding readers that each country in Europe has its own heritage and traditions, which include different ways and methods for collecting environmental and geographic data and different traditions on how to analyze and visualize the data, including different coordinate reference systems (sometimes more than one in each country), projections, and vertical reference systems. These different traditions mean that it is not enough for an SDI in Europe to help users find and access data. It is also necessary to understand the meaning of what we are accessing to make appropriate use of it.

This means, in turn, that we need to develop not only translation tools to help overcome the language barriers but also agree on reference frameworks, classification systems and ontologies, data models, and schemas for each of the data themes shown in table 1 against which the national data can be transformed or mapped. This is necessary because we cannot ask the Member States and their national and local organizations to reengineer all their databases. Thus, the approach adopted is to develop agreed-upon European models and systems of transformation (on the fly or batch) so that the level of interoperability necessary for key European applications can be achieved. The approach sounds simple, but putting it into practice is very complex, as it has already required three years of work to develop an agreed-upon methodology (the Generic Conceptual Model) and tools; mobilize hundreds of experts in different domains; and deliver and test the first round of specifications for the Annex I data themes, with Annexes II and III to follow in the coming years. A visit to the INSPIRE Web site (inspire.jrc.ec.europa.eu/index.cfm) in the data specifications sections demonstrates the huge amount of work involved.

The Organizational Model

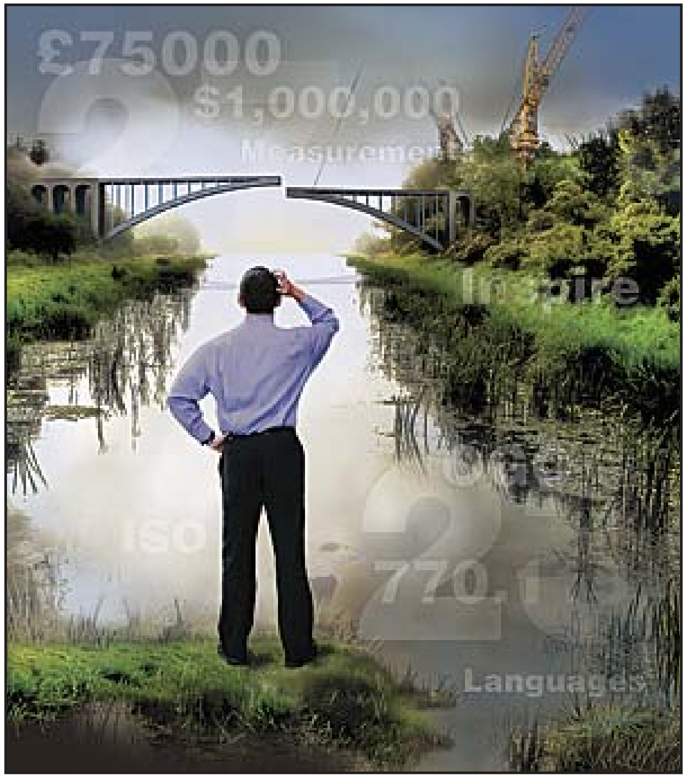
The organizational model put in place to develop INSPIRE is one of its more interesting features, drawing significant attention from outside Europe. In essence, it is a huge exercise in public participation, the like of which is most unusual in policy making, at least in Europe. From the outset, it was recognized that for INSPIRE to be successful and overcome the barriers to data access and use identified earlier, it was necessary for the legislators, implementers, and practitioners in the Member States to come together and agree on a shared understanding of the problem and possible solutions. Therefore, an expert group with official representatives from all the Member States was established at the beginning of the process in 2001, together with working groups of experts in the fields of environmental policy and geographic information to formulate options and forge consensus.

The INSPIRE proposal was subject to an extended impact assessment (inspire.jrc.ec.europa.eu/reports/fds_report.pdf and inspire.jrc.ec.europa.eu/reports/ inspire_extended_impact_assessment.pdf) to identify potential costs and benefits before opening for public consultation. The revised proposal was then debated by the Council and European Parliament over a three-year period before final adoption in 2007. This process in itself is a good example in democracy, but the more interesting aspect is the way in which interested stakeholders are continuing to participate in all the ongoing activities required to develop the INSPIRE implementing rules (i.e., the follow-up legal acts and detailed technical guidance documents).

To organize this process, two mechanisms have been put in place: the first is to engage the organizations at European national and subnational levels that already have a formal legal mandate for the coordination, production, or use of geographic and environmental information (called Legally Mandated Organizations, or LMOs). The second mechanism aims to facilitate the self-organization of stakeholders, including spatial data providers and users from both the public and private sectors, in Spatial Data Interest Communities (SDICs) by region, societal sector, and thematic issue. The central roles that SDICs play in the development of implementing rules include the following:

- Identify and describe user requirements (to be understood as acting in line with environmental policy needs, as opposed to "maximum" requirements beyond the scope of INSPIRE and beyond realistically available resources).
- Provide expertise to INSPIRE drafting teams.
- Participate in the review process of the draft implementing rules.
- Develop, operate, and evaluate the implementation pilots.
- Develop initiatives for guidance, awareness raising, and training in relation to the INSPIRE implementation.

LMOs have similar functions but also play a central role in reviewing and testing the draft implementing rules and in assessing their potential impacts in respect to both costs and benefits.



An open call was launched on March 11, 2005, for the registration of interest by SDICs and LMOs that were also asked to put forward experts and reference material to support the preparation of the implementing rules. The response was immediately very good, with more than 200 SDICs and LMOs registering within a month, putting forward some 180 experts (funded by them) from which we have set up drafting teams to help in developing the first batch of technical documents. At the present time, a second call for experts is open on the INSPIRE Web site to support the development of Annex II and III specifications, and an Internet forum (inspire-forum.jrc.ec.europa.eu) has also been set up for Member States to share experiences and tools to help implement INSPIRE. Table 2 shows the extent of the community directly involved in shaping the policy and the technical documents.

The Inspire Community in 2009
361 Spatial Data Interest Communities (SDICs)
198 Legally Mandated Organizations (LMOs)
300 experts (drafting teams and working groups)
238 experts for Annex II/III latest call
3,087 user organizations registered on the INSPIRE Web site

Table 2: The INSPIRE Community in 2009.

Three aspects are particularity important in understanding the work and the challenges of the drafting teams: first, each expert represents a community of interest and, therefore, has the responsibility to bring to the table the expertise, expectations, and concerns of this community; secondly, each drafting team has to reach out to all thematic communities that are addressed by INSPIRE. As a matter of comparison, it is worth recalling that the U.S. NSDI defined only seven framework themes: geodetic control, orthoimagery, elevation, transportation, hydrography, governmental units, and cadastral information, most of which have a federal agency that is taking the lead in data collection and management. The implication for the drafting teams is that they have a much more difficult task in collecting and summarizing reference material, seeking common denominators and reference models, and developing recommendations that satisfy user requirements without imposing an undue burden on those organizations that have day-to-day responsibility for data collection and management across Europe. Seeking compromise between different requirements and perspectives is crucial to the work of each drafting team.

Last, but not least, it is important to note that the drafting teams have ownership of their work. They make the recommendations and submit them for review to all the registered SDICs and LMOs and the representatives of the Member States. It is only after they have taken on board all the comments received that the Commission takes ownership of the draft implementing rules and submits them for internal consultation. After revision and checking, the draft implementing rules go through the final round of the democratic process before becoming a new legal act. This involves qualified majority voting by the representatives of the Member States and the scrutiny of the European Parliament.

The complexity of this participatory approach is certainly innovative not only in relation to the developments of SDIs but also more generally to the formulation of public policy at the European level. The outcome produces both consensus-based policy and the development and maintenance of a network of stakeholders that make it possible to implement more effectively this distributed European SDI.

The Challenges

Although a great deal of work has clearly taken place with the support of many stakeholders, there are still several organizational and technical challenges (and opportunities) that need to be addressed.

Organizational: The most immediate challenge is to maintain the momentum and the high level of commitment of all stakeholders and the experts contributing to the development of the implementing rules. This is not trivial and requires a notable amount of resources (time, money, expertise, commitment) to ensure that stakeholders feel ownership of the process, which then becomes a prerequisite for more effective implementation. Just to give an example of the scale of the task, the development of the data specifications for Annex I themes involved addressing more than 7,500 comments received from hundreds of stakeholders and organizing some 350 meetings (both physical and virtual) over a two-year period. If you consider that there were 8 themes in Annex I and another 26 to do, in addition to the revisions and maintenance of all guidance documents already created, then you have a sense of this facet of the organizational challenge. The INSPIRE forum is one way to address this challenge, but managing expectations, ensuring real participation, and delivering the benefits are key aspects we constantly need to focus on.

Another facet, which is even more important, is the organizational challenge in the Member States to implement INSPIRE. The INSPIRE Directive asks Member States to establish and maintain their SDIs, nominate an organization as a contact point with the Commission, and set up appropriate coordinating mechanisms, all of which have given rise to a flurry of activity across Europe. In many countries, SDIs already exist and work well at national and subnational levels. So the effort is more focused on agreeing on a division of responsibility than in setting up new structures. In other countries, INSPIRE offers an opportunity for the organizations that have been leading SDI developments for years to get their just recognition and acquire new status and legitimacy.

Of course, the difficult financial climate of this period makes it potentially more challenging to invest in new infrastructures and ways of working. Hence, the challenges in most countries are to leverage resources available from different sources (European, national, international) and/

or ensure strong synergy between the investment required by INSPIRE and those committed in related projects, for example, in the framework of e-government. In this sense, the work needed is critical not only to align sources of funding but also to ensure that initiatives, standards, systems, and deployments are well coordinated and that they do not duplicate, or contradict, each other. Readers of this article who are familiar with large public-sector organizations will know how challenging this may prove to be.

Underpinning this organizational challenge are the key issues of awareness, education, and training. Although we have involved thousands of people in the development of INSPIRE, and most national-level organizations in the Member States are aware of this initiative, there is still much to do. Even in the organizations involved in INSPIRE, sometimes only a few people are actively participating, and the level of awareness of INSPIRE and its future impacts may be lost to other parts of the same organization.

Moreover, many public-sector administrations at the subnational level still have limited or no knowledge of INSPIRE. This is partly due to (1) insufficient dissemination efforts in the Member States; (2) local and regional authorities only becoming more directly involved when the data themes they are responsible for, which are mainly in Annexes II and III, are addressed by INSPIRE; and (3) the complexity of the technical documentation being produced at the present time, which very few people can understand or use. This brings us to the education and training issues. Even if we take a very simplified view of an SDI and assume that all it involves is creating metadata and setting up OGC-compliant services for discovery, view, and access, then where are the technicians versed in the relevant standards and technologies who will be able to implement these services across hundreds of datasets in the thousands of organizations across Europe? Who is training them? Where are the technical colleges and universities forming such competent technical staff? Where is the training material consistently being designed and translated across Europe so that everybody implements exactly the same specifications? And, where are the courses to train professional users (city planners, environmental engineers, social scientists, etc.) on the added value of the SDI to their work? The answer, of course, is that we still have to build up this capacity.

There have been notable efforts in respect to the professional users such as the Center for Spatially Integrated Social Science in the United States (csiss.org) and several EU-funded projects in Europe (e.g., vesta-gis.eu), but the demand far outstrips the supply, and often, the funding to support these projects is limited to a few years, typically three or four. An interesting effort to overcome this short-term funding problem is represented by the Vespucci Initiative for the Advancement of Geographic Information (GI) Science (vespucci.org), a not-for-profit, self-funded initiative bringing together leading GI scientists and practitioners in intensive weeklong courses to foster interaction and exchange of experience along the "training the trainers" formula. After eight years of operation, some 500 participants have lived the Vespucci experience, and thousands more will have benefited from the indirect effects of being trained by the Vespucci alumni.

Technical: The main challenge here is to develop and maintain an infrastructure that works and that delivers added value. As indicated earlier, the suite of international standards and specifications available is sometimes not mature enough to deliver or is subject to different interpretations, change, and inconsistencies. To give one small example, at the core of SDIs is metadata. The international standards for metadata for datasets and services are ISO 19115 and ISO 19119, respectively. The application schema for both is ISO 19139, but these schemas can be found at two different locations: the ISO repository for official standards and the Open Geospatial Consortium Schema Repository. Unfortunately, the schemas available at these two sites differ because of the different versions of Geography Markup Language (GML) they use.

This is now being addressed, but it is just one example of the many problems one has to face in practice. The devil is always in the details, and in the case of INSPIRE, we took the view that it was not feasible to include all the very detailed specifications down to rules for encoding into a legal act, as any change in standards, technologies, or good practice would then require lengthy procedures to amend the legislation. As a result, the INSPIRE implementing rules are short and only say what functionalities are required, leaving the detailed implementation to nonbinding guidelines documents. This has its drawbacks, as we cannot guarantee that everyone will use the guidelines and that interoperability will be achieved immediately. On the other hand, experience has shown that we are still making small adjustments to the guidelines for metadata two years after their approval. Had they been set in tablets of stone (i.e., legally binding), there is no way that we could be able to make any change fast enough.

So, in practice, we adopted a more pragmatic approach, setting up an Initial Operating Capability Task Force with representatives from the agencies in charge in every country to implement INSPIRE. With them we can discuss in detail how they are implementing their services, what seems to work, and what does not; make the necessary changes and adjustments; and disseminate good practice, as well as share tools (and reduce costs). INSPIRE is a process, not just an artifact!

A second challenge is to facilitate the transition from a spatial data infrastructure perspective, that is, the "extended GIS metaphor" used in the introduction, which only addresses relatively few technical experts, toward a spatial information infrastructure, a service providing information products and analyses that are of wider use to nonexperts. This requires turning many of the functionalities and analytic processes encoded in GIS software and usable by few trained geospatial professionals into geoprocessing services that can operate in established workflows over the datasets available on the Web and provide answers to questions posed by the many who are not experts.

The research issues here are many and include eliciting and formalizing processes and models from experts; turning them into geoprocesses, which can be understood and used across disciplines (including explanation of the theoretical underpinning of models so that they can be used appropriately); and selecting the appropriate service to go with the appropriate data to contribute to addressing a question in ways that are methodologically robust. Some of these challenges were addressed, for example, by the ORCHESTRA project (eu-orchestra.org/overview.shtml), but in that instance, all the geoservices had to be chained manually, which would not scale up in a global setting with thousands of datasets and services available. So we need automatic or semiautomatic means of making the right choices and links.

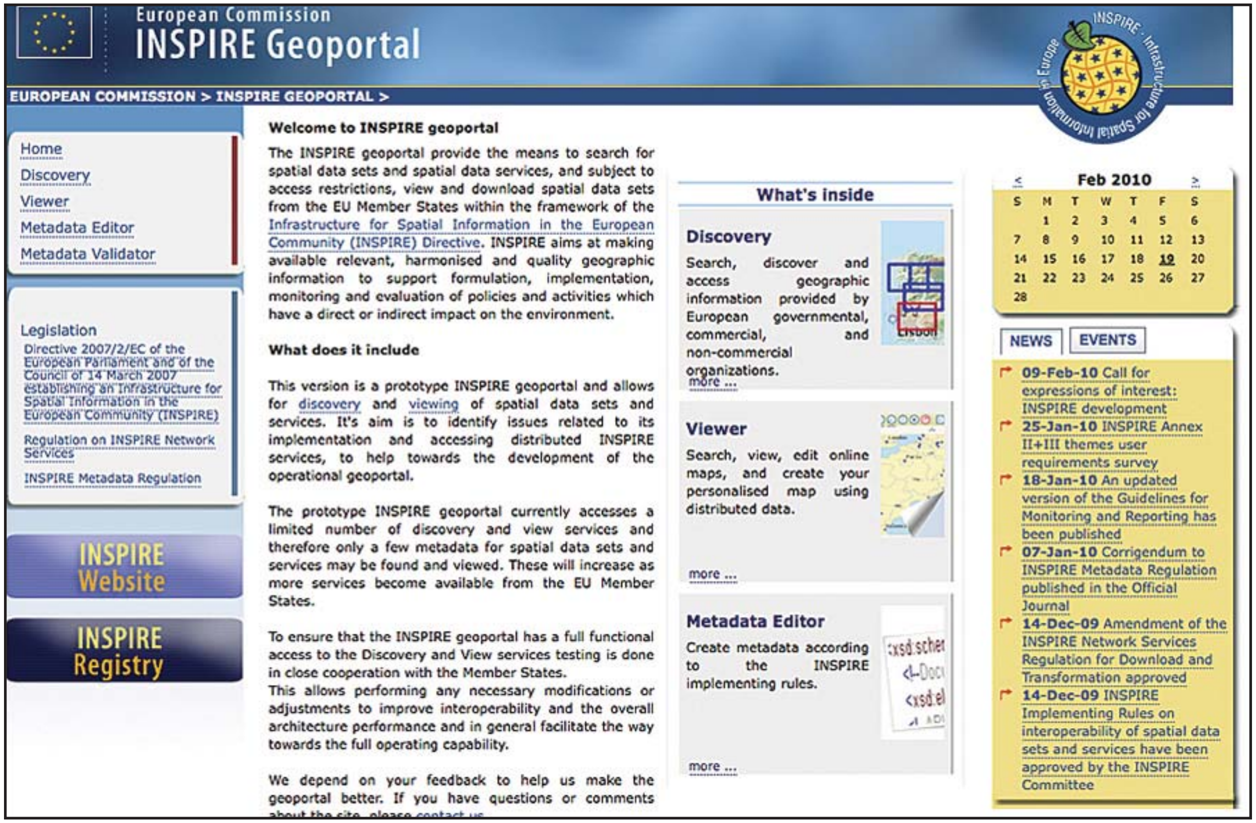
To add spice to these challenges, there are also always new ideas and technologies to understand and harness. So as we were settling in to implement service-oriented architectures (SOA) for SDIs with the corollary of ISO metadata, OGC discovery services, etc. (i.e., following the paradigm of the library that separates the resources from their metadata), along came Linked Data (linkeddata.org) with Resource Description Framework (RDF) to provide semantically rich descriptions of resources and their linkages. Of course, Linked Data and SOA are not necessarily at odds. However, this is a good example of the way one needs to build the infrastructure for today with a view to where we should be going tomorrow.

Toward the Next-Generation Digital Earth

To help sharpen our vision of the future, the Vespucci Initiative brought together in 2008 a number of environmental and geographic information scientists from academia, government, and the private sector to consider the changes that have taken place since the 1998 Digital Earth speech by U.S. Vice President Al Gore (isde5.org/al_gore_speech.htm). The meeting was an opportunity to consider the major technological developments that have made it possible to bring the experience of Digital Earth to hundreds of millions of people in their homes and desktops. It also reviewed the many public-sector-led initiatives aimed at organizing geographic information (SDIs and INSPIRE, the Global Earth Observation System of Systems initiative [earthobservations.org], the International Society for Digital Earth [digitalearth-isde.org], etc.) and the major private-sector developments aimed at organizing world information geographically. These have made it possible for citizens to contribute and share geographic information easily and interact with each other in what is labeled as Web 2.0.

Overall, the emerging view was that there is a need to bring together these seemingly parallel worlds: top-down official information and bottom-up citizen-provided information. On this basis, we articulated a revised vision of Digital Earth to help guide our effort. This vision recognizes the need to integrate scientific and public- and private-sector data to help us understand the complex interactions between natural, man-made, and social environments over time and across space—a framework to help us realize what has changed or is likely to happen, when, and why. To support this vision, we also identified key research topics on which to focus our energies, including improved methods for the spatiotemporal modeling of heterogeneous and dynamic data (citizen provided, sensors, official), the visualization of abstract concepts in space (e.g., risk, vulnerability, perceived quality of life), and ways to assess and model reliability and trust in information coming from many different sources (for more details, see ijsdir.jrc.ec.europa.eu/index.php/ijsdir/article/view/119/99).

You could argue that with all the work we still have to do to develop and implement INSPIRE in Europe, we can ill afford to look for new organizational and technical challenges and research topics. Yet we should never lose sight of why we are building these infrastructures and investing significant public resources to do so. They are not ends in themselves but a means to improve our understanding and stewardship of the environment and develop our knowledge-based society. Without a clear view of where we want to go and what is needed to get there, we will not be able to guide the process effectively and address the grand challenges of today and tomorrow. The *Next-Generation Digital Earth* paper provides an initial contribution in shaping the longer-term view, and we welcome your feedback and contributions on inspire-forum.jrc.ec.europa.eu/pg/groups/98/next-generation-digital-earth.



The INSPIRE geoportal (inspire-geoportal.eu).

About the Author

Max Craglia works in the Spatial Data Infrastructures Unit of the Joint Research Centre of the European Commission. This unit is responsible for the technical coordination of INSPIRE, working closely with other Commission colleagues in the Directorate General for the Environment and EUROSTAT. Craglia edits the *International Journal of Spatial Data Infrastructures Research* (ijsdir.jrc.ec.europa.eu) and is one of the founders of the Vespucci Initiative for the Advancement of Geographic Information Science (vespucci.org).

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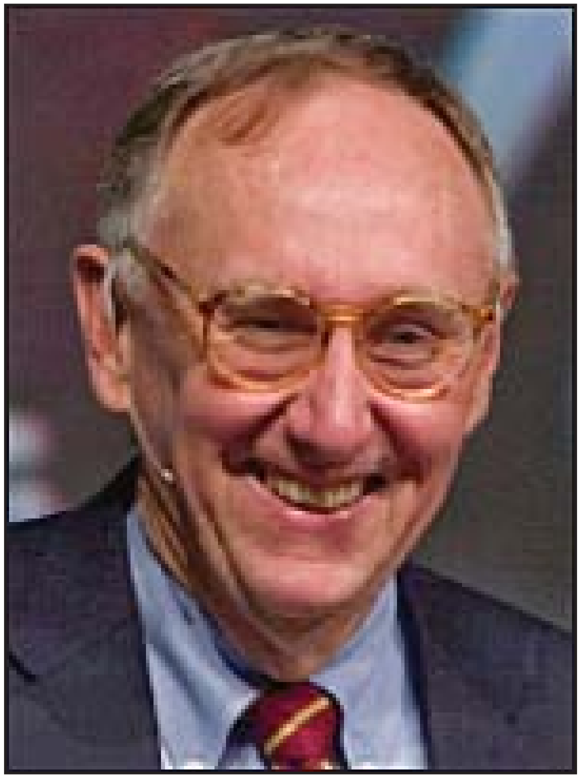
GIS in a Changing World

By Jack Dangermond

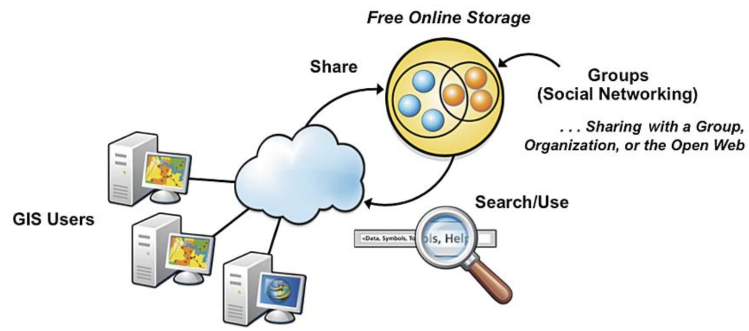
The cloud. Crowdsourcing. Neogeography. Collaboration. The geospatial industry, the IT environment, and the world around us are all changing rapidly. We often talk about how GIS is changing the world. But today I want to spend some time talking about how the world is changing GIS.



GIS has a long history of successfully adapting to new technologies, applications, customer types, and business models. From mainframes to minicomputers, UNIX workstations to PCs, desktops to the enterprise, each round of technical innovation has led to improvements for GIS. Today, GIS continues to evolve in response to infrastructure changes. The distributed computing environment enabled by the Web introduces a whole new set of challenges and opportunities. Merging with and adapting to the latest advances are making GIS easier to use, more collaborative, more powerful, and ultimately more useful for the work you do every day.

The Cloud

Cloud computing delivers technological capabilities on demand as a service via the Internet. Rather than the classic computing model of operating system plus software applications with files and database storage, "the cloud" model consists of services, clients, hosted content, and virtual machines. In other words, you do not load and run software and store data on your computer; you log in and use the system in the cloud. In addition to cloud computing on the public Internet, the same pattern can be implemented within a smaller, more secure community (private cloud) using the same concepts.



With ArcGIS Online, users share maps, data, and applications with specific groups or the world.

Cloud computing is emerging as an important technology trend in almost every industry, including the GIS community, and rapidly moving into the mainstream. We announced recently that ArcGIS 10 is cloud ready, which means that people will be able to rent and deploy GIS servers in the cloud, quickly and easily scaling their system up to solve large problems. For many users, this will provide a more efficient solution for maintaining infrastructure. Also, for many government agencies, it provides a solution for them to serve their data without the cost of administering hardware.

Crowdsourcing

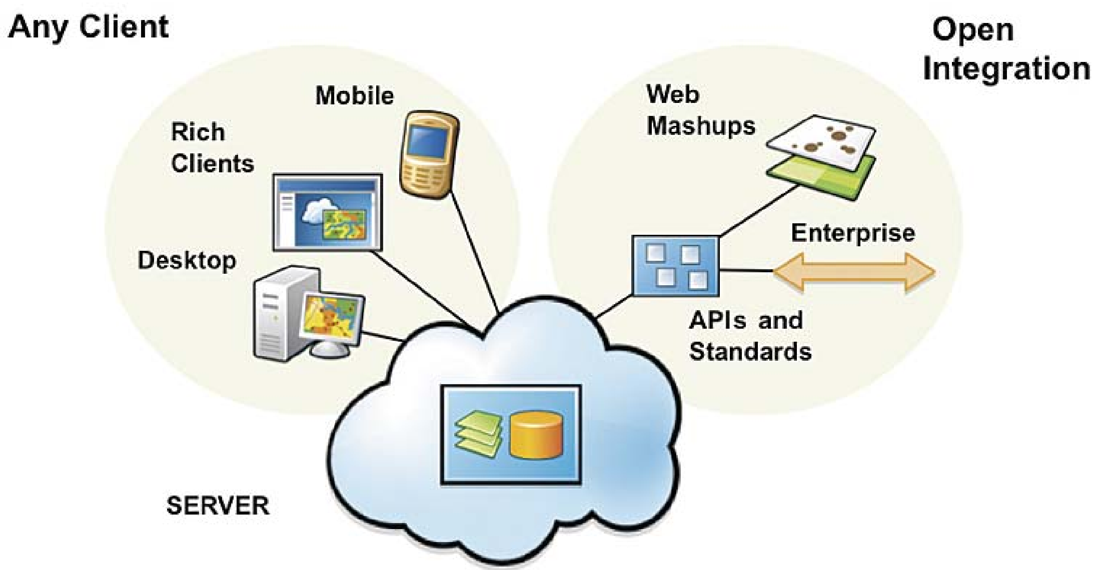
Sometimes referred to as volunteered geographic information or user-generated content, crowdsourced data is contributed by nonauthoritative sources (e.g., everyday citizens). The challenge for GIS practitioners is to ensure the usability of this data in a GIS workflow or to turn this crowdsourced data into useful geographic knowledge. This can mean checking the data to make sure that it is authoritative; it can also mean getting involved in data collection, structuring the process to ensure that the collected data has meaning and is appropriate as well as authoritative.

Long the keepers of purely authoritative data, GIS practitioners are beginning to take crowdsourced data seriously. Crowdsourcing gives ordinary citizens the opportunity to provide feedback directly to the government. It can significantly augment authoritative datasets. It provides extraordinary opportunities for citizen science. And it can put a virtual "army" of volunteers on a large project in short order.

GIS tools supporting crowdsourcing will change the way organizations collect and manage spatial data. New features in ArcGIS 10 give users the ability to modify geographic content within any Web mapping application and provide a venue for online communities to become active contributors to geodatabases. Web editing makes it easy to capture ideas and observations for distributed problem solving and extend GIS editing capabilities to more people within the organization. These capabilities allow everyone—from authoritative data editors to citizens on the street—to contribute content to the geodatabase. This will enrich GIS, giving GIS practitioners new types of data to use, manage, interpret, and incorporate into their work.

Neogeography

The neogeography movement—emphasizing ease of use, visualization, mashups, etc.—has been successful at changing the way society uses and interacts with geographic knowledge. Purveyors such as Google and Microsoft have made great advances in basic mapping, visualization, and mashups and, in the process, have shown us new user interface patterns. Esri is learning from these new patterns, incorporating such ideas into our next generation of software. As a result, the distinction between the world of neogeography and the GIS world is gradually disappearing.



"The cloud" supports both enterprise and Web deployments, transforming GIS access, usability, and collaboration.

One of our primary goals is to make our technology much more straightforward. We believe ArcGIS 10 is an order of magnitude easier to use than previous versions. This simplification comes from a new focus on how people will use the information and capabilities of GIS, resulting in a simple yet powerful system for working with maps and geographic knowledge. These changes will greatly increase usability by GIS practitioners as well as society in general.

Collaboration

New collaborative technologies are redefining how we work together and share information at every scale. This collaboration crosses traditional lines, such as organizational boundaries, professional domains, and geographic borders. Sharing gives people access to vast stores of knowledge that were previously difficult or impossible to obtain and leads to more informed decision making.

ArcGIS is now online. This means that users can share and discover maps and apps and create mashups through virtually any client—ArcGIS Desktop, smartphones such as iPhone, and browsers. Developers can also leverage ArcGIS Online to build and deploy applications. Having ArcGIS Online gives users the power to quickly find, share, and use geographic content from Esri as well as the user community. Through ArcGIS Online, GIS professionals will create knowledge, maps, and models and easily publish them for anyone to use. They will share their work through groups that they can create to collaborate on specific projects and by building communities with common interests.

No one organization can create the GeoWeb or own the entire global spatial data infrastructure. This will be done by thousands of individuals and organizations all over the world creating geoservices and building applications on top of this infrastructure, using new collaborative tools.

GIS Is Changing

GIS has proved to be a flexible, adaptive technology, evolving as the ecosystem around it changes. At each step in this evolution, GIS has not just adapted to these changes but embraced them, becoming more powerful and more valuable. Recent technological advances are helping us reenvision what a GIS is in a new context. As a Web-hosted or cloud-based system with ready-to-use maps and apps, GIS is rapidly moving toward the vision where it can be used anywhere, anytime, by anyone.

Crowdsourcing engages citizens in spatial data collection and civic participation, empowering everyone to participate.

How we use GIS, the way we interact with it, and the way it interacts with the world are all changing. While some of this change has been and will be driven by new tools and technology from Esri and others, the biggest driver of change is you, the GIS user. We're not redefining GIS; you are. You're telling us what technologies we need to embrace; what new functionality we need to add; and perhaps most significant, you are showing us through application of these new technologies how GIS can be used in ways we never dreamed possible.

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Getting to Know the Mapping Sciences Committee

By Keith Clarke, Chair, Mapping Sciences Committee, the National Research Council

Important to the GIScience research community and agenda, especially as far as the federal government is concerned, is the Mapping Sciences Committee (MSC), a standing committee of the Board on Earth Science Resources of the National Research Council. What is this committee; where did it come from; what are its activities and responsibilities; and how do they impact the world of geographic information science, especially with regard to research and development? In this essay, the current MSC chair attempts to answer these questions and reveal MSC as a unique and important vehicle for advancing the science relating to geographic information in the United States.

Introduction

To understand the Mapping Sciences Committee, it is first important to understand the role that the National Academy of Sciences (NAS) has played in United States history. The NAS origins lie in the Civil War, when President Abraham Lincoln was attempting to get access to the highest level of expertise and knowledge available to the small and stretched federal government. The Civil War Act of Incorporation, signed by Lincoln on March 3, 1863, established service to the nation as the dominant purpose of the National Academy of Sciences. The initial mission was to "investigate, examine, experiment, and report upon any subject of science or art" whenever called upon to do so by any department of the government. With only a small number of initial members, the early NAS took on studies commissioned by the government on everything from weights and measures to currency to the permanence of military gravestones. Slowly, the workload increased, such that in 1916 the academy established the National Research Council (NRC) at the request of President Woodrow Wilson to recruit specialists from the larger scientific and technological communities to participate in advising the nation during World War I. With the armistice in 1918 and the formal end of the war in 1919, Wilson issued an executive order asking the academy to perpetuate the National Research Council for the peacetime to follow. This arrangement has persisted: subsequent executive orders by President Dwight Eisenhower in 1956 and President George H. W. Bush in 1993 have reaffirmed the importance of NRC and further broadened its charter. The academy has enjoyed presidential support, most recently when President Barack Obama addressed NAS on April 27, 2009, stressing the value of expert scientific advice to the nation.

Today, the National Academies perform an unparalleled public service by bringing together committees of experts in all areas of scientific and technological endeavor. Experts serve pro bono to address critical national issues and give advice to the government and the public. Four organizations now comprise the National Academies: Institute of Medicine, National Academy of Engineering, National Academy of Sciences, and National Research Council. Members of the National Academy of Sciences are elected to the prestigious office and include GIScientists such as Michael Goodchild, Waldo Tobler, and Luc Anselin.

While NRC has conducted many mapping-related studies, MSC has somewhat more recent origins. In 1989, NRC established MSC to provide "independent advice to society and to government at all levels on scientific, technical, and policy matters related to spatial information." MSC's initial years coincided with the developing vision of a U.S. National Spatial Data Infrastructure.

Public Domain Geospatial Data

Two early reports in particular set forth many of the arguments that later found their form in the many projects to make public domain geospatial data available over the Internet and the World Wide Web. In 1990, the Office of Management and Budget (OMB) established the Federal Geographic Data Committee (FGDC), an interagency group that has remained important in the development of standards, policy, and Web portals ever since. In 1994, under President Bill Clinton, Presidential Executive Order 12906 was issued, calling for a national "Spatial Data Infrastructure," formalizing standards across the government and smoothing the way for accessible and useful geospatial data from many agencies, such as the Census Bureau, National Oceanic and Atmospheric Administration (NOAA), and the United States Geological Survey (USGS). By the end of the 1990s, the vision of ubiquitous and highly accessible data for the general public saw several practical implementations, including MapQuest (1996) and TerraServer (1998). MSC input had led federal agencies to think seriously about public data, open access, and value-added information.

Since 2000, we have seen the rise of the concept of a Digital Earth; the 2002 Revision of Circular A-16, *Coordination of Geographic Information and Related Spatial Data Activities*; the 2002 *National Map* (which was reviewed in concept by MSC); the e-initiatives and Geospatial One-Stop (2003); and, by 2005, the popularization of new Web mapping and visualization technologies.

The Promise Becoming Real

Much of the promise of concepts examined in the early MSC studies had, in effect, come into existence. Given this, MSC's scope not only started to broaden for reasons of national needs but also because GIScience was already being considered a mature, rather than an emergent, field of study.

The scope of MSC includes the following:

- Fundamental research and science for advancing geographic information technologies
- Policies affecting the development and use of spatial data throughout society
- Technological and institutional developments needed for improving the capabilities of spatial data infrastructures
- Coordination opportunities and efforts from local to global scales for the collection and dissemination of spatial data
- Human resources and education in support of the advancement of geographic information science
- Hardware and software systems in support of the advancement of geographic information science and spatial data infrastructure developments

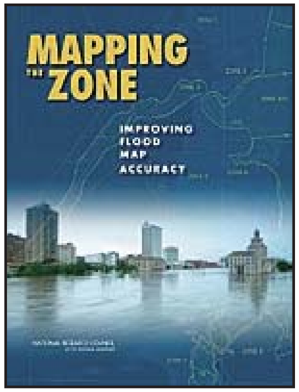
MSC Range of Activities

The Mapping Sciences Committee still performs important functions and often drives major issues surrounding geographic information science. The committee's membership is appointed, and appointments are carefully screened to balance the user communities that the committee serves, including the government, industry, and academia. All NRC committees are held to rigorous standards of independence and peer review. Goals are to provide an impartial forum for discussing geospatial issues, develop emerging study ideas, respond to agency and congressional requests, conduct outreach, and host the National Geospatial-Intelligence Agency (NGA) Academic Research Program Symposium. Most meetings have both open and closed sessions; open sessions are public meetings, and a great deal of the information assembled and used (including the reports as PDF files) is distributed either via Web sites or the National Academies Press (nap.edu).

The Mapping Sciences Committee organizes and oversees studies that provide independent advice to society and government at all levels on scientific, technical, and policy matters relating to spatial data. It also addresses aspects of geographic information science that deal with the acquisition, integration, storage, and distribution of spatial data. Furthermore, through its studies, the committee promotes the informed and responsible development and use of spatial data for the benefit of society. The committee primarily does this by commissioning studies, assembling teams of well-qualified individuals willing to serve on those committees, and seeing the studies through to their results by holding a workshop or producing a major report.

The committee members' responsibilities include surveying and assessing the field and its development and soliciting ideas on problems and opportunities from the broader community (agencies, academia, the private sector). This is sometimes done by having theme meetings, where briefings and discussions during one day of the twice-yearly meetings are devoted to an area with the potential for a new study. The committee also nominates ad hoc committee membership and oversees the follow-up to the various reports created. In most cases, MSC deals with selecting a report topic, writing and clarifying the statement of task for the study, collaborating with the report's sponsors, and nominating members of the ad hoc committee. At that point, the ad hoc committee takes over the task of conducting the study, often spread over multiple meetings, workshops, briefings, etc. The ad hoc committee writes the report, which is edited and subjected to rigorous external peer review.

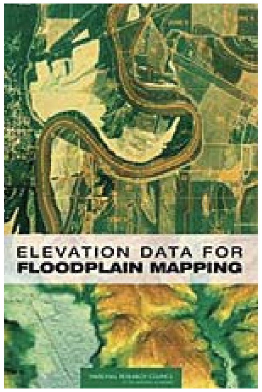
The last few years have been very active for MSC, with a strong sequence of reports published, many of which have drawn a great deal of attention and interest nationally.



In 2009, MSC released the report *Mapping the Zone: Improving Flood Map Accuracy*. This study examined the factors that affect the quality and accuracy of flood maps; assessed the costs and benefits of map improvement efforts; and recommended ways to improve flood mapping, communication, and management of flood-related data.

This research has proved valuable in follow-up activities related to flooding and hurricane impacts. The study concludes that even the most expensive aspect of making more accurate maps—collecting high-accuracy, high-resolution topographic data—yields more benefits than costs and that continued investments should be made in updating and improving flood maps.

This study was sponsored by the Federal Emergency Management Agency (FEMA) and NOAA.

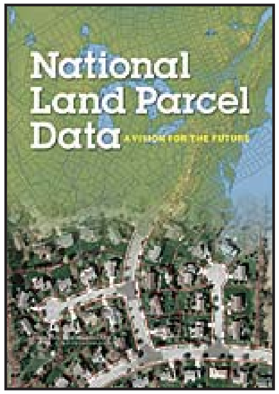


Mapping the Zone followed another flood-related report from 2007, *Elevation Data for Floodplain Mapping*. That report examined the adequacy of the basemap information available to support FEMA's floodplain map modernization program.

The report concluded that existing land surface elevation data is not adequate to determine whether a building should have flood insurance and recommended that high-accuracy lidar data be collected nationwide and incorporated into the National Elevation Dataset that USGS maintains for flood mapping and other applications. This report was a direct response to a congressional request.

Many NRC reports have been related to the basics of collecting geospatial data for the nation. The report *National Land Parcel Data: A Vision for the Future*, also from 2007, assessed the status of land parcel data (also known as cadastral data) in the United States and concluded that nationally integrated land parcel data is necessary, feasible, and affordable. The report recommended ways to establish a practical framework for sustained intergovernmental coordination and funding that are required to develop a nationally integrated land parcel data system.

This highly circulated study was sponsored by the Bureau of Land Management, the Census Bureau, the Department of Homeland Security, the Federal Geographic Data Committee, and Esri.



The year 2007 was a bumper year for MSC. Also published that year was *A Research Agenda for Geographic Information Science at the United States Geological Survey*, which assessed current GIScience capabilities at USGS, recommended strategies for strengthening these capabilities and for collaborating with others to maximize research productivity, and identified research areas.

The report called for an initial focus on improving the capabilities of the *National Map*, which required research on information access and dissemination, data integration, and data models.

USGS, which sponsored the study, has placed into action many of the report's recommendations, including a new release of the National Map Viewer. The year 2007 also saw completion of an important report reflecting lessons learned from Hurricane Katrina in 2005. *Successful Response Starts with a Map: Improving Geospatial Support for Disaster Management* was a report designed to assess the use of geospatial data, tools, and infrastructure in disaster management. It recommended that significant investments be made in training of personnel, coordination among agencies, sharing of data and tools, planning and preparedness, and development of tools.

Sponsors were the National Aeronautics and Space Administration, NGA, NOAA, and USGS.

These reports cover most of the scope of MSC's research tasks, examining technologies and science challenges surrounding issues of national importance. By holding regular meetings and briefings and by focusing on meeting themes, MSC continues to strive toward providing guidance and leadership on national geospatial issues. Other groups—professional societies, trade organizations, the National Geospatial Advisory Committee, and state and local organizations—and many other entities follow the GIScience industry and its needs. What distinguishes MSC are its forward-looking focus, a foundation in science, support from rigorous peer review, and the ability to make recommendations likely to influence policy.

The list of ongoing issues and studies is continuously evolving. Current studies and meeting information, including membership, are available from the committee Web site at dels.nas.edu/global/besr/MSC. MSC hopes to remain at the heart of the nation's activities surrounding geospatial data and information and to continue to serve the nation as we "investigate, examine, experiment, and report upon" the mapping sciences, a field where the United States often leads the world.

About the Author

Dr. Keith C. Clarke is a research cartographer and professor. He holds an M.A. and a Ph.D. from the University of Michigan, specializing in analytic cartography. He joined the faculty at the University of California, Santa Barbara, in 1996. Clarke's most recent research has been on environmental simulation modeling, modeling urban growth using cellular automata, terrain mapping and analysis, and the history of the CORONA remote-sensing program. He is the author of the textbooks *Analytical and Computer Cartography* (Prentice Hall, 1995) and *Getting Started with Geographic Information Systems*, 5th Edition (Prentice Hall, 2010). He is now the chair of the Mapping Sciences Committee of the National Research Council.

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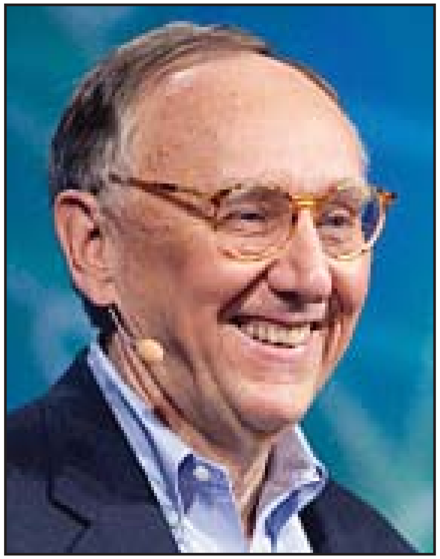
Opening the World to Everyone

By Jack Dangermond

The work of GIS professionals is changing our world. You are working on virtually all the big challenges facing society today, from global climate change and managing natural resources to health care, environmental conservation, and making our cities more livable. Among all these efforts, there is a common thread: visualization through mapping has become our universal language. This language is the most effective way to communicate geographic knowledge and is especially useful in helping make our governments transparent, accountable, and engaged with citizens. Geographic knowledge itself is becoming a new kind of infrastructure, driving all the agencies in regions and countries of the world to work together in new ways.



Esri recently concluded its 30th Annual International User Conference. More than 13,000 people were in attendance, coming from 134 different countries and 6,000 different organizations, representing a wide variety of disciplines, with a multitude of interests. The collaboration, camaraderie, and sharing we experience every year at the User Conference are quite inspirational. For those who were able to attend this unique event, we appreciate your participation and thank you for your valuable contribution to the community. Esri president Jack Dangermond has provided this summary of his thoughts behind this year's conference theme "GIS: Opening the World to Everyone."

The New Explorers

Geography—the scientific foundation of GIS—was for many years concerned with exploring and describing our world. Early explorers led grand expeditions to the poles, to the tops of mountains, to the bottoms of the oceans, the farthest reaches on the globe. Through their explorations, they discovered a new understanding of how the world works, and they came back to share their new understanding with everyone else.

About 50 years ago, a new kind of geography was born—I like to call it *computational geography*—which opened up our world to new forms of exploration: not just treks to the tops of mountains but research and analysis of the relationships, patterns, and processes of geography. This is leading to a much deeper understanding of how our world works. This new exploration leverages computers, mapping, and geographic science. The early explorers were driven by curiosity, as we saw with Waldo Tobler, David Simonett, and John Borchert. Some, like Roger Tomlinson, Carl Steinitz, and Duane Marble, were more interested in the applications of geographic information. Their work led to the development of a new technology: GIS. GIS has advanced the science of geography itself, implementing systematic measurements, digital data models, quantitative analysis, and modeling—the underpinnings of everything that supports the work of geospatial professionals today.

Much of our world remains unexplored, and there are many geographic problems left to solve—population growth, environmental degradation, loss of biodiversity, climate change, globalization, lack of sustainability, urbanization, health care, poverty, hunger, and more. We still have a long way to go to develop a comprehensive understanding of our world. And we need the participation of everyone—not just government administrators, scientists, and GIS professionals, but *everyone* deserves a voice in these important issues.

Today, thanks to new Web mapping technologies and visualization, everyone can be an explorer. Everyone now has tools to examine the earth in different ways. Everyone has the potential to discover something new. This democratization of exploration and spatial analysis will lead to a better, more complete, more equitable understanding of our world and open new dimensions in our relationships with each other and our planet.

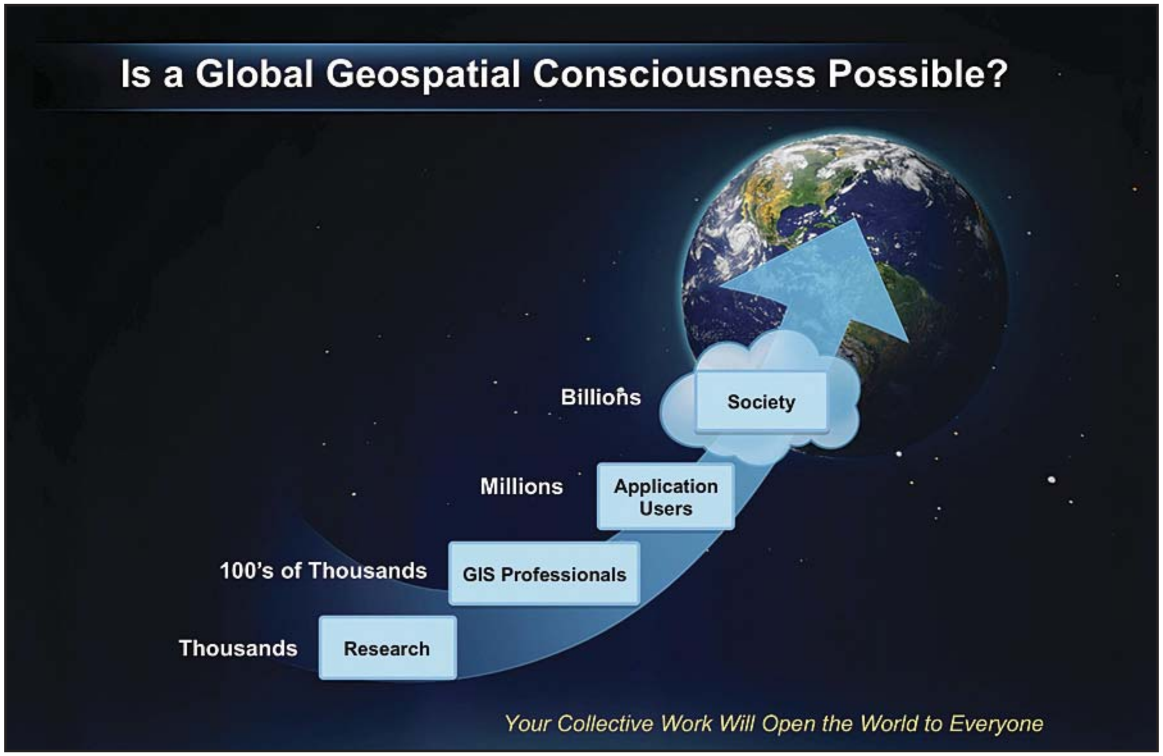
Our New Infrastructure

GIS is already the tool of choice for organizing our geographic knowledge. Professionals have widespread access to this important body of knowledge and leverage it every day to support complex decision making. For the next step in GIS evolution to occur, we must find ways to share this knowledge with everybody else—to integrate this geographic knowledge into everything we do. Building communities—working across disciplines, across geographies, across organizations, and across cultures—is a key aspect of this sharing. Is it really possible to develop a global vision of GIS, leveraging our collective geospatial investments and knowledge, and make GIS available to everyone?

For GIS evolution to occur, we must find ways to share geographic knowledge with everybody and to integrate this knowledge into everything we do.

Many forces are currently converging to facilitate the opening of geographic knowledge to everyone. Computing technology continues to evolve, following Moore's Law: *The number of transistors on a chip doubles every two years*. Machines, networks, and the Internet have become faster, and there has been the recent explosion in the use of mobile devices. Measurement is also increasing with more sensor networks, real-time delivery, and the recent addition of geographically referenced crowdsourced data. GIS software is also evolving in its ability to handle temporal data and provide full 3D support and, therefore, many more new features, all while becoming much easier to use. At the same time, GIS is coevolving with geographic science, increasing our understanding of relationships, patterns, and processes that are now extending into a greater understanding of networks. And perhaps the biggest force of all is the opening of government: open data policies are providing the underpinnings for this information to come together, creating a collective geographic understanding, truly opening our world to everyone.

GIS professionals are playing key roles in making this geographic knowledge available: sharing data and publishing apps and services. They are also developing more collaborative approaches—from connecting to other parts of their organizations to serving citizens with information, using maps as a common language to communicate with and engage everyone in a geographic context.



All these efforts are creating a Web-based, geospatial platform for creating, storing, sharing, and using geographic knowledge, and people will become increasingly dependent on it. When technology is so universally adopted that society becomes highly dependent on it, it can be considered infrastructure. And that's really what we are all building here: a geospatial infrastructure that is the basis for opening geographic knowledge to everyone. GIS has been a very useful tool for more than 40 years, but we are about to discover its true power: the power to transform the way we all live.

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