The National Map
From Geography to Mapping and Back Again

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Abstract

When the means of production for national base mapping were capital intensive, required large production facilities, and had ill-defined markets, Federal Government mapping agencies were the primary providers of the spatial data needed for economic development, environmental management, and national defense. With desktop geographic information systems now ubiquitous, source data available as a commodity from private industry, and the realization that many complex problems faced by society need far more and different kinds of spatial data for their solutions, national mapping organizations must realign their business strategies to meet growing demand and anticipate the needs of a rapidly changing geographic information environment. The National Map *of the United States builds on a sound historic foundation of describing and monitoring the land surface and adds a focused effort to produce improved understanding, modeling, and prediction of land-surface change. These added dimensions bring to bear a broader spectrum of geographic science to address extant and emerging issues. Within the overarching construct of* The National Map, *the U.S. Geological Survey (USGS) is making a transition from data collector to guarantor of national data completeness; from producing paper maps to supporting an online, seamless, integrated database; and from simply describing the Nation's landscape to linking these descriptions with increased scientific understanding. Implementing the full spectrum of geographic science addresses a myriad of public policy issues, including land and natural resource management, recreation, urban growth, human health, and emergency planning, response, and recovery. Neither these issues nor the science and technologies needed to deal with them are static. A robust research agenda is needed to understand these changes and realize* The National Map *vision. Initial successes have been achieved. These accomplishments demonstrate the utility of* The National Map *to the Nation and give confidence in evolving its future applications.*

Introduction

The U.S. Geological Survey (USGS) was formed in 1879. It replaced and expanded on the four Great Surveys of the American West conducted between 1867 and 1879 by F.V. Hayden, Clarence King (who became the first USGS Director), John Wesley Powell (the second USGS Director), and George Wheeler (Thompson, 1979, pp. 4–5; Rabbitt, 1989, pp. 5–12). The USGS provided the scientific information needed to settle and develop the western United States into a natural resource-based economic engine that could propel the Nation into the industrial age. From its beginnings, the USGS was a combined economic and environmental agency. Much of its focus was on the exploration, enumeration, and economic and cultural evaluation of the Nation's land resources. Initially, geology and geography were at its core. Hydrology was added shortly thereafter. Biology was added 115 years after the USGS was founded, producing an agency with an integrated scientific focus on land, water, and biologic resources and processes.

Soon after the establishment of the USGS, many of its geographic activities were realigned into a civilian topographic mapping effort unparalleled in the world. With Federal-State partnerships that began in 1885,[1] the USGS completed several series of increasingly larger scale topographic maps. By the early 1990s the USGS had completed first-time coverage of the conterminous United States, Hawaii, and Puerto Rico with 1:24,000-scale (1:20,000-scale in Puerto Rico) topographic maps and had produced other medium-scale topographic maps of Alaska and the Trust Territories. This graphic database of approximately 55,000 individual quadrangle maps has been used widely by citizens, government agencies, and the private sector.

It took more than 33 million labor hours and more than 1 billion nominal dollars[2] to compile the 7.5-minute series of topographic maps. The total would be far greater in current dollars[3] owing to inflation. For a single Government agency to replicate this effort and to maintain the currentness of the maps requires a radical approach. These maps are the only nationally consistent synthesis of base geographic information that exists from border to border and coast to coast. This information database is an irreplaceable national treasure of immense importance that, if recast and kept current, will continue to increase in value to the Nation (Ryan, 2002).

Spurred by a dynamic geographic information system (GIS) industry during the 1990s, the means of map production shifted away from capital-intensive map factories. Given the wide-spread availability and affordability of underlying technologies, base mapping is no longer the sole purview

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[1]Undated USGS table titled Cooperative Topographic Mapping funds expended annually in fiscal years (1885–1968).

[2]Nominal dollars are based on actual expenditures at a particular time, not accounting for inflation or any other adjustments.

[3]Current dollars are dollars from other time periods converted into present-day dollars, to factor out the effects of inflation.

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of the Federal Government. Decentralization has become the norm. Source data and the standard and custom map products produced from those data are generated by State and local governments, the private sector, academic institutions, and not-for-profit nongovernment organizations. With decentralization, however, came the added cost to the Nation of redundant mapping efforts and the resulting incompatible data owing to inconsistent content, format, and accuracy. In recognition of the need for standardized digital base cartographic and geographic data, the USGS began to produce nationwide map theme coverages in the late 1980s and early 1990s (Kelmelis, 2003). These national datasets are the foundation for *The National Map* or, in the metaphor put forward by the National Academy of Sciences, the blanket (NRC, 2003).

The blanket and quilt metaphor illustrates the concept that the Nation is fully represented by a standardized set of data layers of a known type and accuracy. The blanket is continually updated by incorporating appropriate data from the quilt, that is, from a patchwork of data produced by and for other government and nongovernment organizations. These data are generally at a higher level of accuracy and can contain more specialized information needed locally. The patchwork, developed with some local entities advancing more rapidly than others, has holes in various layers. The blanket covers those holes while the patchwork is being developed. The patches provide the information to update the blanket, or national datasets. Thus, *The National Map* is a community effort to meet the need for a National Spatial Data Infrastructure (NSDI). However, *The National Map* is more.

The USGS recognized the implications of widely distributed production and analysis capabilities for base geographic data and maps and established an innovative partnership program in the mid-1990s (USGS, 1997, revised 2001) to expand cooperation among map-producing organizations. It also became clear that the USGS's national responsibility for mapping and geography required more emphasis on developing a scientific understanding of Earth surface processes. USGS expanded its geographic work to meet the needs of a fundamental research discipline of describing (mapping), monitoring, and understanding geographic processes (Ackerman, 1958). It has also expanded to meet the contemporary scientific needs of modeling and predicting change (Kelmelis, 1997; Kelmelis, 2001) on and near the land surface, the critical zone (NRC, 2001) in which human activities take place, to increase the relevance of its spatial science activities to society. The geographic science spectrum (Plate 1) is the foundation upon which to organize the next logical step in USGS mapping: building *The National Map*. Meeting such a complex vision requires addressing many of the research opportunities identified by the National Academy of Sciences (NRC, 2002).

An important consideration is that *The National Map* is not merely a USGS-specific data production and distribution activity. It is a national program that includes all levels of government and many types of non-government organizations and it incorporates the full spectrum of scientific activities. One of the major challenges is to develop new ways to facilitate partnerships of the willing to make the geographic information available, accessible, and applicable. This goes beyond using current technology and organizational relationships. *The National Map* must be sufficiently flexible to adapt to the changing technological, scientific, and cultural environment.

Essential Elements of *The National Map*

With individual theme-based national map coverages well established and a growing cadre of cooperators and contractors involved in data collection and standard topographic mapping, it is time to move from quadrangle-based topographic mapping to a national geographic information synthesis. This synthesis will be based on a community approach of sharing digital geospatial data that observe agreed-upon minimum standards and specifications with the added benefit of techniques to use these and other data. This strategy is supported by a patchwork of "best available" State and local data that are generated to satisfy local needs and that often are of better accuracy, content, and resolution than national datasets.

To treat critical national priorities, *The National Map* must represent the most current characterization of the landscape and understanding of Earth processes. Thus, ongoing monitoring efforts must exist, both on the national scale with remote sensing and other sources of synoptic data and at local scales with updates produced by States and local governments. The results of monitoring add to the spatial-temporal volume of national data and support an improved understanding of processes taking place at and near the Earth's surface. Models built with that understanding help provide forecasts of the effects of natural and anthropogenic influences on the landscape. The monitoring, understanding, and models that allow for forecasts and predictions are part of *The National Map*. Thus, *The National Map* is a shared effort to ensure that the necessary geographic information and understanding are available to meet 21st century demands.

Describing (Base Geographic Data)

The foundation of *The National Map* (Plate 2) is the base geographic data necessary to provide the digital topographic map of the 21st century. These are as follows:

- High-resolution digital orthorectified imagery;
- High-resolution surface elevation data, including bathymetry;
- Vector feature data, including hydrography, transportation (roads, railways, airports, and waterways), structures, government unit boundaries, and publicly owned lands;
- Geographic names, such as those for physical and cultural features derived from the U.S. Board on Geographic Names and engineered features (e.g., highways and streets); and
- Land-cover data that classify the land surface into categories, such as open water and high-density residential.

Building on current national datasets, *The National Map* will be seamless and consistently classified, enabling users to extract information for irregular geographic areas, such as counties or drainage basins, and to spatially analyze the information. Data resolution and completeness will vary depending on geographic area and need. For example, *The National Map* will contain higher resolution elevation data in areas of subtle relief variation, such as flood plains, to support hydrologic and hydraulic modeling.

Positional accuracy will be sufficient to vertically and logically align features from different data themes. Thus, stream reaches will correspond to land surface slope, and boundaries will align with corresponding features, such as roads or rivers. *The National Map* will contain data that surpass the standards that have been applicable to the primary series of topographic maps.

All content of *The National Map* will continue to be documented by metadata that comply with Federal Geographic Data Committee (FGDC) standards. These data will be sufficiently versatile to be accessed and used on evolving open systems that are designed to encourage interoperability and the sharing of data and techniques.

Monitoring

Monitoring takes several forms:

- Local, State, tribal, and Federal entities often monitor and map changes to land-surface features in their jurisdictions or mission areas. These mapped changes will be incorporated into *The National Map* using innovative business arrangements.
- Partnerships can provide important monitoring opportunities. Although the frequency and type of monitoring will vary from place to place, a well-defined baseline of monitoring is

necessary to enable change detection. The satellite imagery and aerial photograph content in *The National Map* will be refreshed periodically, on the basis of collection resources and demand. These will include the current and historic Landsat data, data from other civil satellite remote sensing missions and declassified military and intelligence satellites, and aerial photographs acquired for mapping purposes.

Aerial photography continues to be an excellent source of high-resolution imagery, although high-resolution satellite data are becoming more available. Land-cover data in *The National Map* are presented in a format that includes all source data, impervious surface and canopy density derivatives, and decision rules for classification. With these elements, and Internet-based access to *The National Map*, users can take advantage of the USGS Land Cover Classification, or they can derive their own custom land-cover classification by manipulating the decision rules. For example, there are many definitions of "forest" based on density of crown cover or percentage tree canopy. *The National Map* land-cover database provides the data and tools to produce a land-cover derivative that matches the user's preferred definition of forest.

Understanding, Modeling, and Predicting

The content of *The National Map*, combined with the power of the Internet to access and download data, knowledge, and capabilities, provides the user with a vast array of possibilities for analysis. Key constituents of *The National Map* include the following:

- The Geographic Face of the Nation, containing statistical information on land-cover condition and change. These land-cover facts are based on *The National Map* data that provide areal and class statistics on two snapshots of land-cover data, 1992 and 2001.
- USGS Land Cover Trends data, showing changes in land cover over the last 30 years. These data can help to answer a variety of questions. Users can display percentage of change through time for a specific geographic area, or they can access the change in specific land-cover classes, such as urban, agriculture, and forests.
- Analytical tools developed and proved during research projects. For example, using the elevation, hydrography, and land-cover data, a user could model areas of inundation from potential flooding.

As USGS geographic research projects are completed, data, tools, new understanding of Earth processes, and techniques will be added to *The National Map*, multiplying the possibilities for analysis. Phenological data, amphibian distributions, pathogen concentrations, climate data, fire fuel maps and fire danger ratings, and accessibility to wilderness areas are examples of future content. Other data and applications can be linked through *The National Map* viewer, such as realtime streamflow from gaging stations or estimated streamflow using basin characteristics from *The National Map* and other data and historic flow statistics from similar watersheds (Reis and Friesz, 2000).

The Initial Version of *The National Map*

The initial version of *The National Map* is based on existing data and scientific information. The National Elevation Dataset, National Hydrography Dataset, National Land Cover Dataset, orthoimagery, and the Geographic Names Information System form the initial data framework. Historical and current Landsat data are also accessible. Statistics on the characteristics of the land surface, links to realtime streamflow data from USGS gaging stations, access to selected process models that will run in the background as Web services with results available to users, and links to publications on the area of interest will also be available. As *The National Map* matures, the patchwork of more accurate and complete local data will be added, along with more sophisticated monitoring, analytical capabilities, and scientific understanding.

Partnerships that exist with the U.S. Environmental Protection Agency, Census Bureau, Forest Service, National Oceanic and Atmospheric Administration, National Imagery and Mapping Agency, and Federal Emergency Management Agency contribute to improvements in the resolution and areal coverage of these key national datasets. As the initial version is improved, emphasis will shift to maintaining data currentness through continuous updating. Data sources include State and local governments, private industry, and local trained and certified volunteers. The coalescence of technologies that support the personal computing and wireless communications industries offers exciting possibilities not only for remote access to national datasets but for feedback from users that will provide timely status update reports. In this way, participation in *The National Map* can be opened to more parties as long as effective safeguards for data quality and consistency are in place.

Although it is intended that *The National Map* will be accessible over the Internet using a browser-based Web viewer (Plate 3) all day, every day, alternative means will also be developed to access the information. This is a particular concern during times of emergency when Internet links are most vulnerable and the need for *The National Map* will be most acute. All data will be broadly accessible with few or no licensing restrictions. Effective business methods that meet public domain information needs, yet provide for commercial profitability of privately produced data, will be required. The incorporation of reduced-resolution or limited-attribution data from private sources into *The National Map* may make this possible.

Users will be able to combine data from *The National Map* with geographic information available from other organizations, such as demographic and socioeconomic data from the Census Bureau. *The National Map* will be a consistent, freely available foundation to which all sectors can reference their specific datasets, such as school district boundaries or wildlife population estimates.

The USGS will continue the tradition of the primary series topographic map by providing a standard product derived from *The National Map*. At first, the USGS will use *The National Map* as a source of updated printed maps. As technology and business partnerships mature, Internet users will be able to create their own maps by defining a geographic area of interest, selecting unique combinations of data, and printing their maps at home or at kiosks that could be available locally at libraries, post offices, recreational suppliers, bookstores, and other outlets.

Four fundamental goals must be met to achieve *The National Map*. These goals capture the transition of the USGS from a primary producer of geographic data to a role that stresses partnership building, standards development, integration of data from diverse sources to ensure national consistency, and improvement of our understanding of the Nation's geography. As a result of this transition, the USGS mapping role in the future will be that of a data producer only when partnership opportunities with other government agencies or the private sector are not feasible. Future USGS data production and maintenance for *The National Map* will be accomplished largely through contracts with the private sector and will have the following key goals:

- Improve the value of the geospatial data available to the natural resources decisionmakers and the public by building *The National Map* distributed databases through partnerships and with State and local governments that collect and maintain higher resolution, more current data. Partnerships are the fibers from which *The National Map* fabric will be woven.

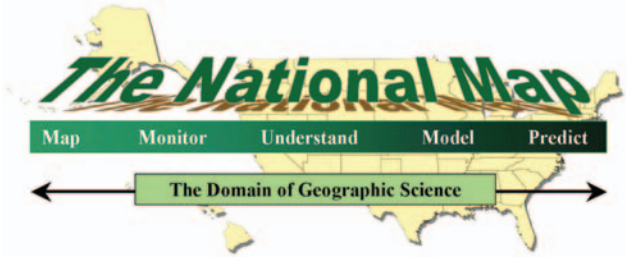

Plate 1. USGS programs span the full spectrum of geographic science to implement *The National Map.* Mapping and monitoring provide the foundation for understanding landscape change and, ultimately, for process modeling and applications of models to predict future changes.

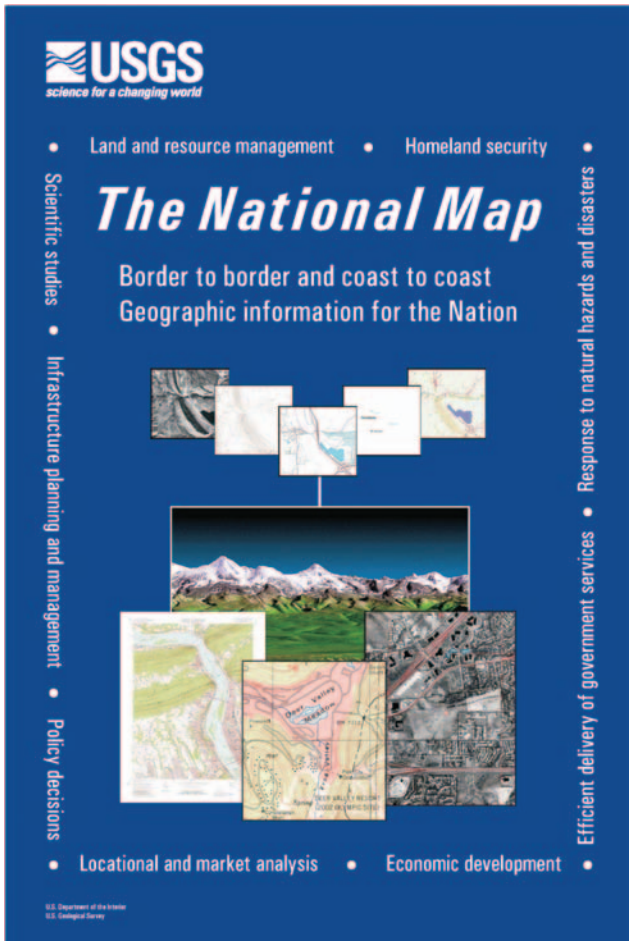

Plate 2. The content of *The National Map* provides a geospatial framework for compiling and referencing specialized data, linking to other higher resolution or enhanced content datasets, and building applications that address numerous geographically based issues.

- Ensure the availability of nationally consistent and integrated geospatial data by leading development and promoting the use of international, national, and FGDC National Spatial Data Infrastructure standards among *The National Map* partners. Data awareness, ease of exchange, and interoperability underlie the leveraging of collective data resources through sharing that minimizes redundancy.
- Expand the understanding of Earth processes by maintaining and promoting access to a long-term imagery archive of the Earth's surface and other regional and global remotely sensed data as part of *The National Map* distributed databases and by developing new scientific knowledge through internal and external partnerships.
- Inform decisionmaking by policy makers, land and resource managers, the public, and others by applying geographic science to understand, model, and predict the rates, causes, and consequences of land surface change over time. This application of geography will be achieved by integrating *The National Map* distributed databases with other data, conducting fundamental and applied research, and effectively communicating the results to the scientific and management communities.

To help establish effective partnerships, it will be increasingly important to have a significant part of our workforce collocated with staff from partner organizations. This will encourage and sustain cooperative activities that emphasize data sharing, distributed data stewardship and administration, and data applications. These offices will be established where there are significant opportunities for collaboration with other governmental organizations and where the location will contribute to the advancement of *The National Map*. The USGS has established offices to coordinate mapping partnerships in selected locations (Plate 4) and expects to open more in the future.

Implementing *The National Map*

The spectrum of geographic science that begins with descriptive mapping and monitoring, that progresses through understanding and modeling, and that results in an ability to predict land surface changes is the basis for *The National Map*. Although today most of our resources are being applied to mapping and monitoring, as the USGS successfully implements *The National Map* vision, greater emphasis will be placed on understanding, modeling, and predicting landscape change. Advances in analysis, modeling, and predicting are needed to improve the content and to identify new needs for the descriptive and monitoring efforts.

The **Cooperative Topographic Mapping Program** ensures the availability of a nationally consistent, seamless, continuously maintained, current and historical, vertically and horizontally integrated framework of base geographic data. The base raster layers of *The National Map* are elevation (National Elevation Dataset), orthorectified imagery derived from airborne and satellite sensors, and land cover (National Land Cover Dataset). The base vector layers are hydrography (National Hydrography Dataset), boundaries, transportation, and structures. Geographic names (Geographic Names Information System) also are part of the base data framework. The best data available to *The National Map* are used regardless of whether they are from Federal, State, local, or other sources, provided they meet minimum standards and specifications for quality and content, as well as requirements for broad accessibility.

The **Land Remote Sensing Program** supports the monitoring of changes on the Nation's landscape through frequently acquired aircraft and satellite imagery and data. Repetitive national coverage is obtained from the Landsat satellite system. Additional remotely sensed imagery and data are obtained from other government and commercial sources. These data are maintained in the National Satellite Land Remote Sensing Data Archive and other databases to feed the requirements of both government and nongovernment users. Access to these data will be through *The National Map* Web viewer and by other methods established with partners. The long-term vision is to distribute these data at a minimum cost to maximize the benefit to society and stimulate the value-added remote sensing applications industry.

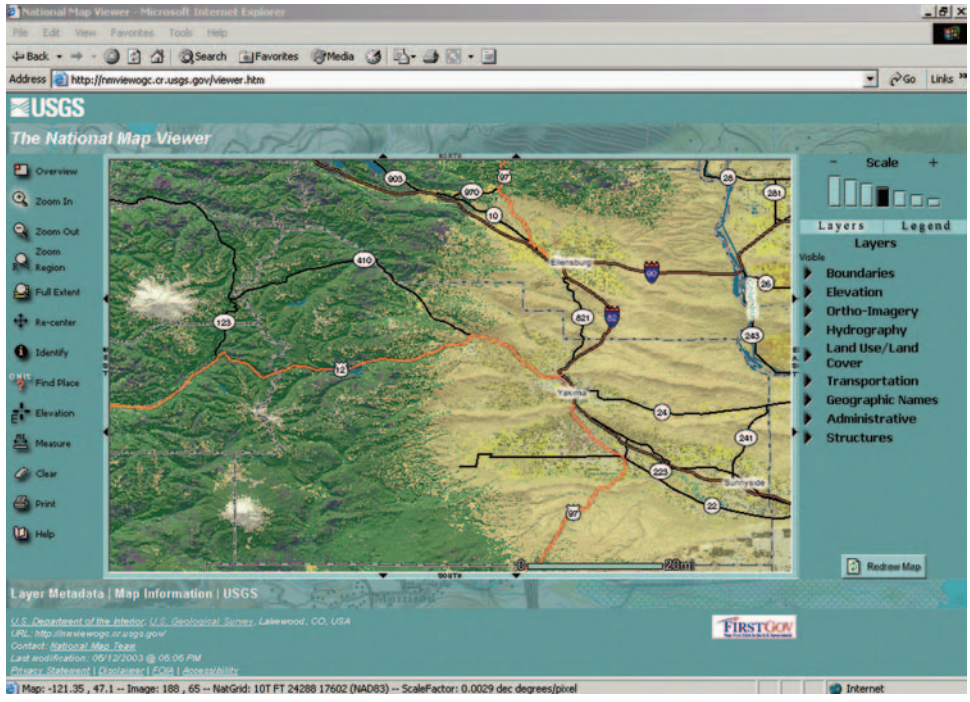

Plate 3. *The National Map* browser-based Web viewer provides access to national datasets, higher resolution location-specific data, and partner implementations.

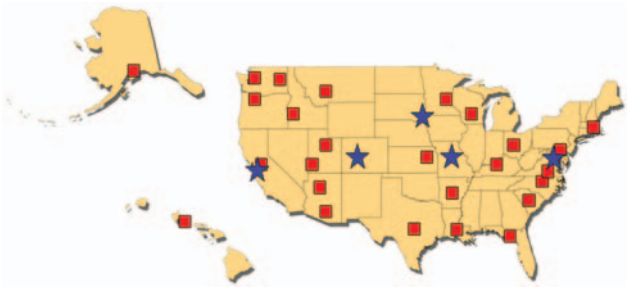

Plate 4. The USGS is relocating its workforce from traditional Mapping Centers (blue star) to field locations, either existing or planned for 2003 (red square). These offices are collocated with other USGS staff and with State and other partners. Collocation fosters sustained working partnerships for maintaining and integrating base geographic data and for applying *The National Map* to geospatial issues.

Concerned with processes that affect or are affected by changes to the land surface, the **Geographic Analysis and Monitoring Program** develops knowledge, models, and prediction or forecast capabilities and incorporates them into *The National Map*. Major tangible contributions to *The National Map* include *The Geographic Face of the Nation* (USGS, 2002) and the status and trends of the land surface, which is an analysis of the condition of land use, land cover, and other land surface variables, how they have changed over time, and the causes and effects of those changes. Additional contributions include modeling tools accessible through *The National Map* viewer. Selected scientific studies prepared in response to policy and management questions will be accessible as well.

All content of *The National Map* will be made accessible through a browser-based Web viewer and portals such as Geospatial One-Stop and will be searchable through a distributed database architecture that supports thematic, feature, and other update options. In addition, the viewer will support access to a wide variety of "best available" data from partners, other data such as Census Bureau information that is referenced to the base data of *The National Map*, and private sector data that provide higher resolution or enhanced attribution data linked to commercial source public domain content in *The National Map*. For instance, in addition to base geographic data and knowledge content, the initial implementation of *The National Map* may be linked to the USGS stream gaging and earthquake monitoring and reporting networks, geodetic control points maintained by the National Geodetic Survey, and other data, such as tax parcel information maintained by county and municipal authorities.

First Steps

Primary series topographic quadrangle maps are the most widely recognized product of the USGS. Why now the impetus to move to a product that is multiresolution, online, and maintained by a network of partnerships rather than continuing to revise our existing maps? The answers are both complex and simple. They are complex because of the incredible workload of maintaining up-to-date information on 55,000 individual primary series maps and because of the costs and logistics of maintaining a warehouse of more than 60,000,000 maps, given the accelerating rate of change on our Nation's landscape. At the same time, the answers are simple because of the clarity with which we understand the Nation's dramatic need to have a current picture at any moment in history of our lands and infrastructure and of their attributes. These geographic information needs now drive the USGS to refocus on what must change to achieve success.

But why change now? We know that the USGS is simply not keeping up with the demand to revise and publish new

topographic maps through existing processes that are rooted in 20th century technologies and business methods. We know that using the proliferation of geospatial technologies of all sorts, many county and municipal governments are producing up-to-date mapping information for their own purposes. These authorities have significant field forces that are directly in touch with landscape changes. We understand that the private sector produces and maintains datasets of great value to the Nation. We know that the Internet provides a vehicle for the rapid sharing of information without regard to distance and at minimal cost. We know that the continued prosperity of the Nation's economy, the well-being of its citizens, and the stewardship and wise use of its natural resources (Plate 5) all depend upon mapping information at some level. To meet these challenges, the USGS must subject its mapping organization, operational philosophy, methods, and products to radical changes.

These are both grand challenges and great opportunities. The USGS established a series of partnership pilot projects (www.nationalmap.usgs.gov) to test the concepts that underlie *The National Map* and to begin cooperative implementations that will be built upon in coming years. The single most important factor in selecting where and with whom to conduct this work was the existence of a partner, or network of partners, that would make a proactive and long-term commitment to *The National Map*. The pilots included the following:

- Delaware, in partnership with the Delaware Geographic Data Committee, the University of Delaware, and the Delaware Geological Survey;
- Lake Tahoe, California-Nevada, in partnership with the Tahoe Regional Planning Agency, California and Nevada State agencies, and other Federal agencies;
- Cape Girardeau, Missouri, in partnership with local agencies and the USGS National Cooperative Geologic Mapping Program;
- Pennsylvania, in partnership with the Pennsylvania Geological Survey and county governments;
- Texas, in partnership with the Texas Natural Resource Information System of the Texas Water Development Board;
- Utah, in partnership with the State of Utah Automated Geographic Reference Center;
- Washington-Idaho, in partnership with Spokane and Pend Oreille Counties in Washington State, Kootenai and Bonner Counties in Idaho, and the Coeur d'Alene Tribe;
- Mecklenburg County, North Carolina, and the city of Charlotte (Plate 6); and
- Landsat 7 seamless data for the entire Nation to demonstrate and validate the USGS's ability to serve large datasets seamlessly over the Web.

These are the lessons learned from the pilots: (1) a reinforcement of the need for agreement on open standards that allow data to flow seamlessly across organizational lines; (2) the value that a lead partner provides in managing the complexities involved in working with multiple cooperators (e.g., a State agency that organizes the counties and municipalities in its State so that the relationship with the USGS is managed through a focal point, as in the Texas and Delaware pilots); (3) the fact that although technological hurdles exist, they are not the principal challenges compared with resources and organizational relationships; and (4) to successfully establish the necessary partnerships, the USGS must do more to accelerate the distribution of its workforce near its partners. Part of the success in working with our pilot partners is attributable to the fact that USGS people are located with or near many of them to provide continuing, direct dialogue and support. The Geography Discipline's decision to aggressively pursue the establishment of a network of distributed offices in cooperation with our partners responds to this need. These pilot implementations are building momentum and will continue to be developed as key starting points for *The National Map*.

The USGS also has sought partnership agreements with other Federal agencies that conduct base geographic data acquisition and mapping operations. Key Federal support from the Census Bureau (roads and boundaries from the Master Address File/Topologically Integrated Geographic Encoding and Referencing (MAF/TIGER) Accuracy Improvement Project), the National Oceanic and Atmospheric Administration (shoreline delineation and bathymetry), the Federal Emergency Management Agency (elevation data), and the National Imagery and Mapping Agency (partnership for high-resolution urban area orthoimagery and feature data) has been encouraging. As part of the Department of the Interior, we are trying to satisfy the base mapping needs of other Department of the Interior Bureaus, especially those with land and resource management missions such as the Bureau of Land Management and the National Park Service, and we are working with them to ensure that their needs are met. It is our goal that in all of these cases, *The National Map* should become the base geographic data foundation of their enterprise GIS implementations that address mission-specific programs.

One factor that has been important in devising *The National Map* implementation strategy has been the increased emphasis within the United States, including the geographic information community, on the protection of life and property. The USGS has a long tradition of providing maps, remote sensing imagery, and other geospatial data for studying, preparing for, and responding to natural and human-induced disasters. One manifestation of the sharpened focus on emergency response has been a significant demand for up-to-date, high-resolution, orthorectified imagery, particularly covering the most heavily populated and developed urban areas of the United States. During 2002 and into 2003, a significant proportion of *The National Map* implementation has been focused on meeting this need. By late 2003, in conjunction with our partners, we will bring current orthoimagery (Plate 7) to *The National Map* for 46 of the Nation's largest metropolitan areas. The USGS is meeting this need through cooperative efforts with the National Imagery and Mapping Agency, other Federal agencies, and State and local governments and, in many cases, through contracting with the private sector.

Additional implementation planning for *The National Map* for fiscal year 2004 and beyond includes the following:

- Establishing additional partnerships with Federal, State, and local governments, the private sector, and public organizations to provide public domain data for *The National Map*;
- Assisting partners to inventory existing datasets, document them using FGDC metadata standards, and publish them in the NSDI Clearinghouse;
- Providing technical assistance to develop and implement commercial translation tools for data that do not meet NSDI standards;
- Developing and implementing data filtering, generalization, integration, and validation tools needed to obtain a nationally consistent representation of USGS and partner data;
- Determining where there are base geographic data gaps and developing cooperative strategies to fill these gaps;
- Developing methods to ingest, store, access, explore, retrieve, and distribute current and historical information from *The National Map*;
- Providing technical assistance to partners to help them implement NSDI and industry interoperability standards and protocols;
- Ensuring 24-hours a day, seven days a week access to public domain data by organizing and, where necessary, operating an Internet-accessible distributed data network;
- Providing browsing, access, visualization, and analysis tools to ensure that users can locate, obtain, and apply the content of *The National Map*;
- Implementing a capability to provide derivative products (such as printed or print-on-demand maps and digital products) from *The National Map* portal to meet the needs of all

users, including those in nondigital environments, such as emergency first responders;
- Publishing the initial draft for the land-cover status and trends report, which will describe the current state of the Nation's land surface and the factors driving land-use and land-cover change;
- Planning for the Landsat Data Continuity Mission to provide continued land remote sensing satellite data beyond the present Landsat system; and
- Developing improved methods to deliver satellite remotely sensed data and other data from *The National Map* at lower costs to users.

Relationship to the National Spatial Data Infrastructure

It has long been recognized that combining efforts and resources to produce maps or using agreed-upon standards and specifications for maps and map data across numerous organizations helps reduce the high cost of map production and maintenance by minimizing redundancy. A joint approach was considered many times in the past at the national level (OMB, 1973; NRC, 1981; NRC, 1994; NAPA, 1998) as well as globally, starting with Albrecht Penik's 1891 proposal for a worldwide system of maps (Wright, 1952, pp. 300–319) which evolved into the International Map of the World (UN, 1963), which was followed by the digital Global Map project. To further cooperation on the national level, the FGDC was established by the Office of Management and Budget (OMB, 1990) to coordinate processes that addressed "multi-agency interests, including the facilitation of exchange of information and transfer of data; the establishment and implementation of standards for quality, content, and transferability; and the coordination of the collection of spatial data to minimize duplication of effort where practicable and economical." The NSDI was recommended by the National Academy of Sciences (NRC, 1993). The National Geospatial Data Clearinghouse, part of the NSDI, was established by Presidential Executive Order 12906 (Clinton, 1994). This Order requires Federal agencies, working through the FGDC, to standardize documentation of their data, establish standards for data exchange for the geospatial data they produce or hold, and make those data available to the clearinghouse network.

The considerable effort expended to establish mechanisms for coordination, standards, and metadata documentation for data awareness and assessment was critical to establishing the NSDI. Also fundamental to its establishment was the creation of nationally consistent layers of base geographic data. At the USGS, this began as the National Digital Cartographic DataBase (NDCDB) (McEwen and Jacknow, 1980). The NDCDB content was built in large part by digitizing features and interpolating raster elevation data from contours on existing USGS topographic maps. It was originally conceived as a quadrangle-by-quadrangle tiled digital database and evolved with advances in technology into a number of seamless national coverage data layers, such as the National Elevation Dataset and the National Hydrography Dataset. Completing this set of framework data layers and ensuring the currentness of their content are critical to achieving the NSDI goals. *The National Map* will improve the accuracies and currentness of these datasets, promote their availability as framework components of the NSDI, and provide links to data of greater accuracy, resolution, and content produced by other organizations. Thus, *The National Map* operationalizes the NSDI and helps to realize its ultimate goal: providing geographic data that are locatable, accessible, assessable, available, and applicable.

Next Priorities for *The National Map*

The National Map is an ambitious and important responsibility. It cannot be accomplished in a short timeframe or with only the resources of the USGS. Because of its magnitude and the complicated, occasionally conflicting, demands placed on its implementation, priorities must be defined to guide its execution. Organized around the themes of availability, accessibility, and applicability, the highest priorities recognize the need to test concepts, meet immediate data and product needs, strengthen the analytical, modeling, and predictive capabilities that build on the mapping and monitoring foundation, and prepare the organizational structure and partnership mechanisms that support *The National Map's* long-term viability and usefulness.

Availability

The highest priority locations for assembling the content for *The National Map* are the Nation's largest urban areas that are home to more than 180 million people, approximately 55 percent of the population of the United States. These concentrated areas cover only about 4 percent of our land area, but they contain much of our critical transportation, health care, banking, industrial, communications, and other infrastructure. The areas were selected by the Homeland Security Infrastructure Program Tiger Team, an interagency committee charged to evaluate urban area data collection requirements and define collection strategies (HSIP, 2002). Not only are current, high-resolution data being acquired through data sharing and contracting processes, but as resources permit, relevant new knowledge and applications capabilities are being built on the data foundation to study issues such as the impacts of suburban growth on water quality and the spread of human diseases (e.g., West Nile Virus).

The data framework that will make *The National Map* a reality includes the national data layers discussed previously. Completing, upgrading, and maintaining these data must be a priority to ensure that a consistent framework exists to which the "best available" data of higher accuracy and increased content from other sources can be linked.

The National Map also relies on frequent monitoring of the land surface for the long-term effectiveness of the program. Because the Landsat 5 satellite has long surpassed its design life and Landsat 7 has experienced a severe malfunction, a plan for the next generation landscape monitoring system is essential. The Landsat Data Continuity Mission is planned to meet the next cycle of data needs. That mission is a top priority for *The National Map*, as is planning for a more stable follow-on program.

Accessibility

Users from all sectors and locations must be able to access and use *The National Map* content and capabilities, particularly in times of crisis when availability, flexibility, and reliability of information and tools for its exploitation are vital. For initial implementation and to demonstrate early capabilities, a common look and feel is important. It will help to ensure that *The National Map* becomes a pathway to all component and linked datasets and to information and applications that promote understanding of the Nation's geography. A portal and browser are part of this initial effort. However, flexibility and the use of open architecture that is system neutral are key to the long term success of *The National Map*, particularly as technology advances well beyond current concepts of browsers, viewers, and portals. Simultaneous access to numerous servers is critical to the blanket and quilt approach described by the National Academy of Sciences (NAS, 2003). Much deeper technology must be engaged so that the relationships between spatial and temporal data and their information elements are clearly defined and embedded in *The National Map* data structure. These will help to ensure access in ways that facilitate the development of new scientific understanding and rapid use of *The National Map* for decision making.

Cost can be as much a barrier to geographic information accessibility as technology. A top priority of the USGS is to develop a funding model that will increase use of *The*

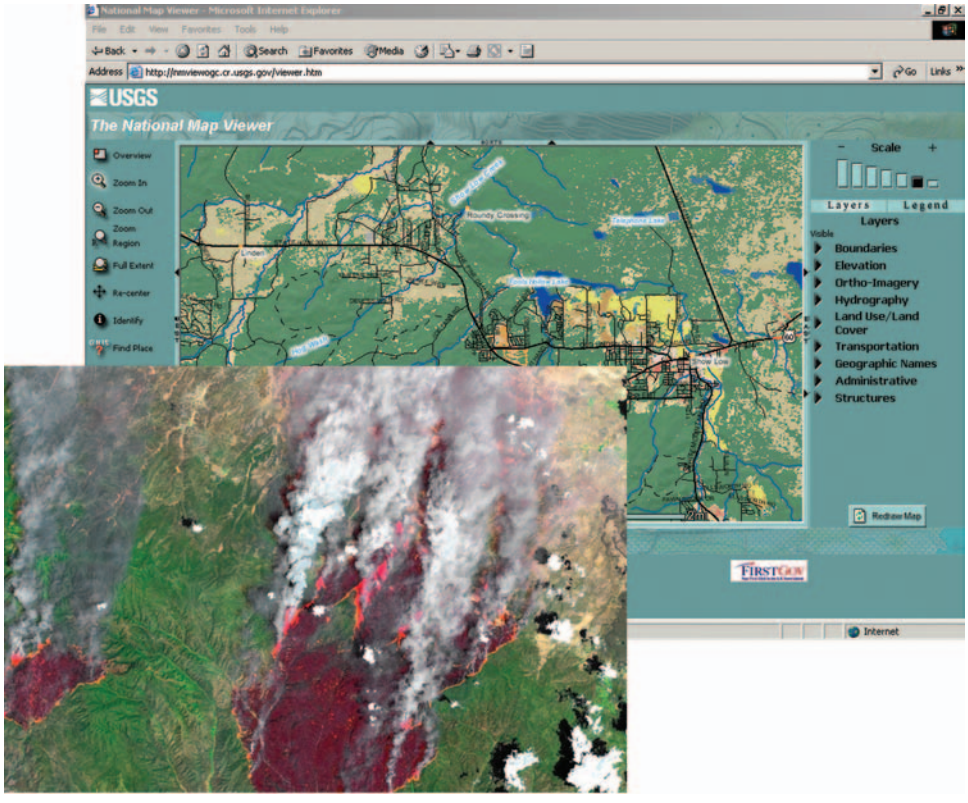

Plate 5. Base geographic information from *The National Map*, including land cover and elevation data, can be merged with wildland fire perimeter information from remote sensing sources (here, Landsat imagery) and meteorological data to analyze, model, and predict fire behavior (Rodeo-Chediski Fire, Arizona, 2002).

Plate 6. *The National Map* partnership with Mecklenburg County, North Carolina, delivers orthoimagery, road centerlines and names, and other local "best available" and specialized datasets through the Web viewer.

Plate 7. The intersection of Wisconsin and M Streets is at the heart of the Georgetown neighborhood in Washington, D.C. True color, 1-foot (0.3-m) ground resolution orthoimagery of the Nation's largest urban centers provides information for urban studies, infrastructure planning and management, and protection of people and property. Orthoimagery is a key theme of *The National Map.*

National Map and other types of data and applications. Alternative financial, technological, and management means are being investigated to protect the system from being unduly burdened by very large downloads of data. Initial intentions are to implement a policy for free downloads of data in reasonable quantities and provide low-cost processes for large-volume access. The USGS also will pursue funding to encourage sustainable partnerships that are needed for efficient and effective data maintenance, sharing, archiving, and dissemination operations. This approach is designed to encourage the use of geospatial information and growth of the value added geospatial industry, and to expand the market for more detailed and custom made commercial data products.

Applicability

Numerous applications depend on USGS topographic maps and data. The first priority for future applications is to identify those that should be included in a fully operational national map, convert them to forms that can be accessed in a distributed computing environment, and provide instructions for their use to the community. The first step for continually improving access to geographic science capabilities is to make them available and to test them through *The National Map* viewer. Thus, a robust suite of applications will be made accessible through the viewer in the near term. Tests of these applications will help improve them for wider use in the future. However, application of existing knowledge is not sufficient to address the dynamic nature of land surface changes and how they will affect or be affected by human activity or natural phenomena, particularly for new and growing issues.

An evaluation of the status and trends of the land surface is also important at the local, State, and Federal levels. This evaluation, kept current to ensure its relevance and delivered in document form through existing publication channels and digitally through *The National Map* Web viewer, will demonstrate how the monitoring and analytical capabilities of *The National Map* can affect our understanding of the Nation's geography.

Research Needs

A leading objective of the USGS is to support the development, testing, and use of *The National Map* as the overarching context of the Cooperative Topographic Mapping, Land Remote Sensing, and Geographic Analysis and Monitoring Programs. Within this organizational setting, supporting innovative research in geography, cartography, remote sensing, and information science and technology, integrated with interdisciplinary science of interest to the USGS subject matter specialists in geology, water resources, and biology, is an important focus. This research is hypothesis or question driven and explores new concepts, approaches, and understanding that will lead to the long-term viability of *The National Map* and enhancement of the science of geography.

Research is needed to evolve the vision of *The National Map* in response to the dynamic technological, scientific, and requirements environment that will unfold over the next 5 to 10 years. Major long-term questions include the following:

- What content, relationships, forms, and structures of geographic data and information are needed to respond to the

various problems facing the Nation? How will *The National Map* best be accessed and distributed? How will its contents be maintained, integrated, and quality assured? How can *The National Map* be kept secure yet remain readily and reliably accessible?

- In an environment where aware and proactive citizens expect that they will have unrestricted access to knowledge and analytical capabilities plus data, how should those be made available in a delivery system? What are the best forms in which they should be presented? How can users identify what is needed and available to solve their problems? How can the geographic community minimize costs and redundancies in meeting these needs? Are there any data to which the general public should *not* have access at all times?
- What must be known about the environmental context (biological, physical, social, economic, etc.) at the critical zone on and near the landscape surface to respond to current and future scientific and management needs? How can this new knowledge be made available and most useful? What are the implications of these needs to the partnerships, methods, and tools of *The National Map*?
- What current, planned, or to-be-developed remote sensing technologies (sensors, data, or tools) can be used to support the science of geography, government programs, and *The National Map*? How can they be used with regard to specific issues such as hazard mitigation, feature extraction, near-realtime observation and monitoring, change detection, and data integration and synthesis?

These high-level questions will stimulate discussion and drive research agendas aligned to the long-term goals of *The National Map*. Other organizations, such as the National Imagery and Mapping Agency, National Aeronautics and Space Administration, Open GIS Consortium, and University Consortium for Geographic Information Science, are studying similar questions. Partnerships with these organizations will aid in advancing the science needed to achieve *The National Map*.

Conclusion

The National Research Council concludes in its report, *Weaving a National Map: A Review of the U.S. Geological Survey Concept of The National Map* (NRC, 2003), that "The USGS Geography Discipline has made a *bona fide* effort to confront its future head-on with the *The National Map* vision. This vision is ambitious, challenging, and worthwhile. It is within the USGS mission and mandate to implement an endeavor of this scope. The committee endorses the USGS's plan for a nationally consistent set of base map data that includes pointers to multiple-scale map and image data."

The leadership of the USGS appreciates this endorsement of *The National Map* and is committed to bringing this bold vision to fruition by applying the full spectrum of geographic science. In 10 years, when our Nation looks back at improvements that will result from the redirection and refocusing of USGS efforts and the multisector partnerships that will achieve *The National Map*, we are convinced that it will be with an enhanced awareness of the power of geographic science and its impact on understanding, protecting, intelligently using, and effectively managing the Nation's landscape.

Additional Information

The National Map vision document (USGS, 2001) and additional information about USGS Geography Program organization, activities, products, and services are available at www.nationalmap.usgs.gov.

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