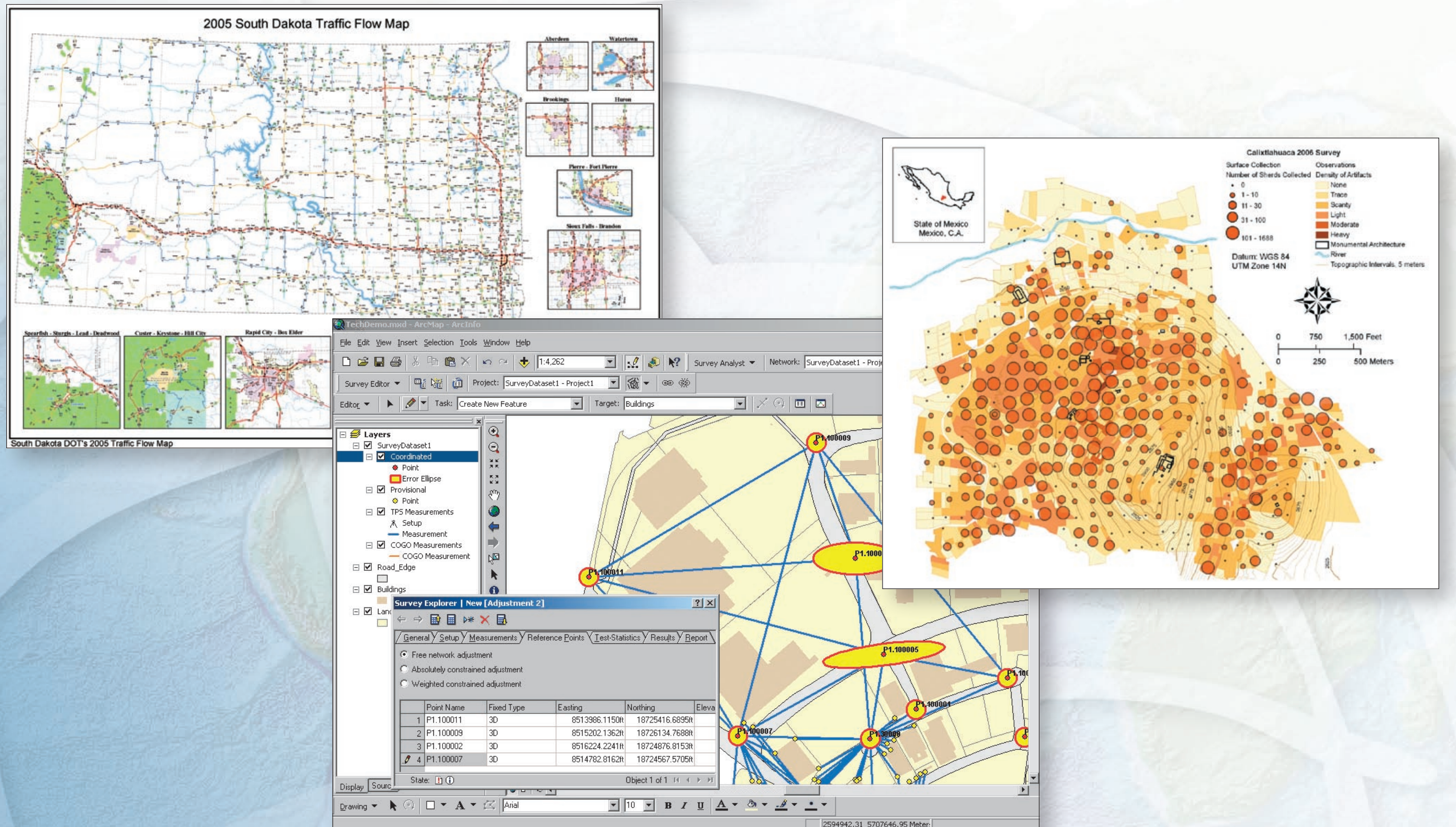
GIS Best Practices

Using GIS with GPS



March 2009

ESRI

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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.

GPS-GAP Changes the Way We View the Earth

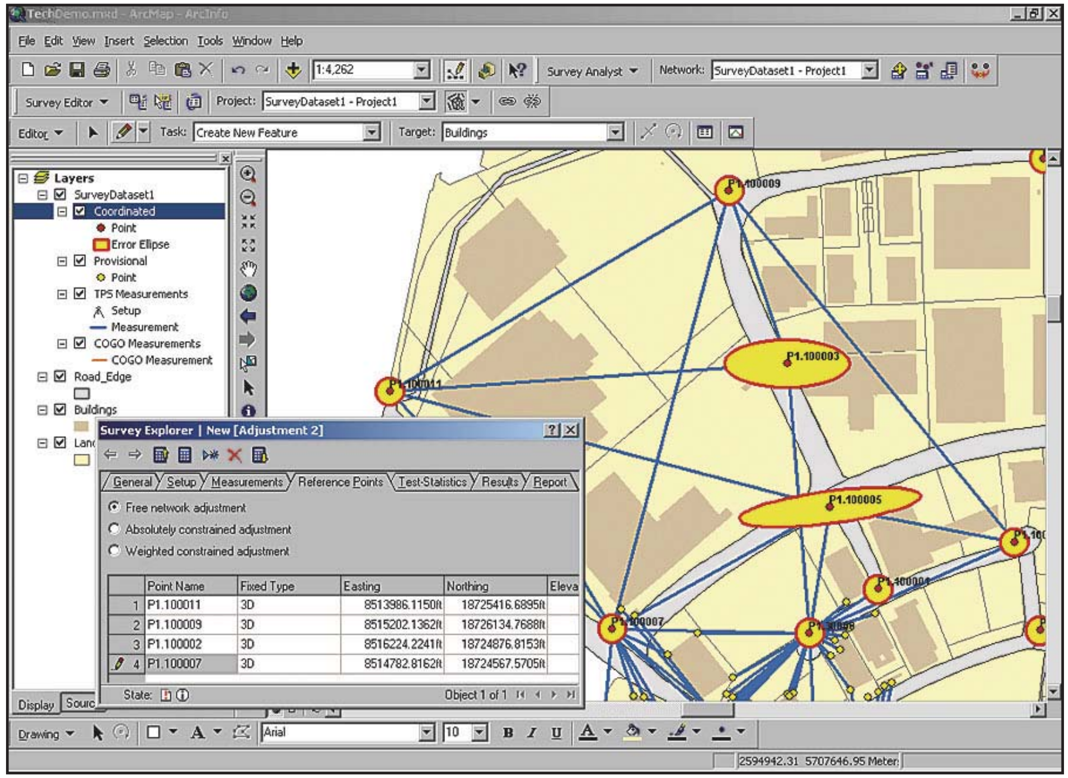
By Alfred Leick

GPS technology has demonstrated stellar performance ever since its inception. The uses and applications have grown at an incredibly rapid rate. From navigation to recreational uses, from mapping to precision surveying and GIS, the ubiquitous nature of GPS is impacting our lives in a positive manner. Many of these applications provide precise positions, some in real time. Delivered with this precision is an implied understanding of some fundamental concepts that are often overlooked. The GPS, Geodesy, and Application Program (GPS-GAP) is an online educational initiative by the University of Maine that offers in-depth knowledge about this fantastic system to help GPS and GIS users understand all the parameters necessary for precise positioning, including the geodetic foundation.

GPS is changing the way GIS users collect and manage geographic data. The high accuracy that GPS provides has GIS professionals storing and managing their data in new ways. GIS now supports a double precision database, and GIS users are developing new methods for improving the spatial quality of the existing data in their systems. GPS provides a key component for this, but there are many considerations when using GPS to obtain and understand accurate positions.

Geodesy—the science that determines the size and shape of the earth and measures its gravitational field—always looms in the background when positioning, regardless of accuracy, whether one applies reductions or transformations that allow plane computations, or whether one applies three-dimensional models recognizing the fact that the earth is round after all. Geodetic methodology provides products such as the NAD83 datum, the ITRF2000 reference frame, earth orientation parameters with respect to inertial space, the geoid, deflection of the vertical, station motions on a deformable earth, and spatial variation of gravity. All these products are available and continually refined, but an understanding of the fundamentals is important to properly employ them.

Examples of primary geodetic measurement tools are laser ranging to satellites and the moon; Very Long Baseline Interferometry (VLBI); and, last but not least, GPS. Whereas VLBI has



GPS observations and total station survey data integrated with local mapping and managed in GIS.

allowed us to reference the earth rotation to the direction of stable extragalactic radio sources with unbelievable accuracy, GPS has advanced geodetic capability by leaps and bounds in a variety of ways. New capabilities that come to mind are the accurate monitoring of plate tectonic motions, mapping of spatial variations of the troposphere and ionosphere (which introduce the majority of errors in GPS measurements), and ultraprecise positioning of near-earth satellites (which carry the sensors that supply important GIS input data streams).

Ever since Eratosthenes of Cyrene's (276–194 BC) determination of "the size of the earth," geodetic science has been driven by the cycle of discovery and increased measurement accuracy, accompanied by mathematical refinement. As discovery generated new questions, the desire for better measurements followed. This cycle is still continuing and also applies to GIS applications.

In step with today's trends in electronics, computers, and the Internet, the tools of GPS and GIS, mixed with geodetic capability, are being placed into the hands of more people than ever. The recent CNN broadcast on the top 25 nonmedical innovations of the last 25 years hinted at the broadening of the user base. It ranked GPS in position six, just after e-mail and above portable computers. The list was assembled by the Lemelson-Massachusetts Institute of Technology (MIT) Program in cooperation with CNN. Of course, the Internet occupied position one on the list.

Emerging local real-time differential networks accelerate the integration of GPS and GIS. Differential networks allow the mitigation of systematic errors in GPS positioning and thereby increase the positional accuracy that is available to users. To be sure, regional differential networks are already widely in use. For example, the Wide Area Augmentation System (WAAS) is a U.S. government-operated real-time network that supports navigation for civil aviation. Another well-known network is the Continuously Operating Reference Stations (CORS) network of more than 1,000 stations operated by the National Geodetic Survey (NGS). These and similar regional networks throughout the world serve their mission well; however, their impact on the data collector in the field pales compared to what is still to come.

The goal of local real-time differential networks with closely spaced GPS tracking stations is to enable ambiguity fixed solutions. Avoiding the details, let it be simply stated that this type of solution somehow manages to estimate the integer number of wavelength ambiguities, as opposed to merely estimating rational values (called ambiguity float solutions). It is the kind of solution that provides centimeter-accurate positioning in real time. The closeness of the stations is dictated by the network's ability to most economically make real-time ambiguity fixed solutions possible. Such networks could, of course, be connected to form regional networks of closely spaced stations. The network stations typically transport their observations via the Internet to a server at some central location and move data from the server to the user's GPS receiver.

Ambiguity fixed solutions are the best that GPS has to offer. This fact does not change even as the modernization of GPS continues; the Russian global orbiting navigation satellite system (GLONASS) regains strength; the satellites of the European Galileo system come on line; or the planned Chinese Compass satellite system completes the fourth leg of the global navigation satellite system (GNSS) of independent global navigation systems, each one featuring some

30 or so satellites. The physics that led to a closely-spaced network of stations to achieve integer ambiguity resolution remains valid, although the reliability of real-time ambiguity fixing will increase with such an abundance of satellites available.

Another development needs to be pointed out. GPS satellites originally (and most of them still do) transmitted one civil code and two encrypted military codes on two different frequencies. Again, without going into detail, ambiguity fixing works better if there are at least two different frequencies (carriers of the codes) available. Receiver manufacturers have developed patented solutions that allow them to use the encrypted codes. A consequence of these patented solutions is that dual-frequency receivers are still very expensive. The trend these days is to make at least two public codes available on the satellites, thus avoiding the need for patented solutions and "naturally" separating the civil and military access points to the satellites. This, together with the pressure of the mass market, should result in a major drop in price for dual-frequency receivers and consequently result in a broader user base for such devices.

Having ambiguity fixed solutions available in real time—the discovery that emerges from the GPS-GIS intersection, supported by a solid geodetic foundation—can only be described as huge. GPS users will be logging their precise GPS positions in GIS servers in real time.

The move of GPS/GIS capability with a geodetic foundation into many hands carries with it risks and pitfalls. After all, GPS still has limitations, mostly dictated by the laws of physics, as mentioned above. Such limitations may cause misinterpretation of results or lead to false conclusions and decision making. Since demanding GPS applications require more than merely pushing receiver buttons, there remains a need for objective quality control of data and an understanding of the mathematics and physics of the observables. Similarly, the ease with which GIS software can display and manipulate data requires a deep understanding of the nature of the data on the part of the serious user.

Because of the inquisitive nature of users, it is inevitable that existing techniques and software capabilities will be pushed to the limit, if not over the limit, to advance discovery. Hence, there is the need for an educational service that seeks to address the GPS-GIS intersection and the geodetic foundation in a unified manner.

My enthusiasm for GPS began during the summer of 1982 at MIT when I tested an experimental GPS receiver, called the macrometer, over a 30 km baseline from Woburn, Massachusetts, to Mount Wachusett. The satellite visibility ranged from about 6:00 p.m. to midnight in New England. Many of the sunset watchers at the summit were puzzled by my activities and impressed by the huge piece of equipment in the back of the station wagon, the abundance of cables, and the strange-looking antenna (so they thought). Their puzzlement about what I was up to was reflected in some of their comments, such as "Is this thing taking off?" or "Are you on our side?" Of course, there was plenty of time until midnight to be entertained by Fourier transforms and such on the computer screen and to ponder the unlimited potential of GPS.

Those long evening hours on top of Mount Wachusett allowed me not only to double-check the amazing repeatability of the observed baseline vector night after night but also to marvel at the science behind all of that. There was the prospect that GPS could revolutionize my field of specialization, geodesy, and that we could gain a better understanding of the variations of the atmosphere. There certainly was curiosity as to what signals the satellites actually transmitted. I was told that it was so weak that it was below the background noise. And yes, there were questions: Why was this antenna so large that onlookers thought it might take off? Why was the computer crunching all night? What precisely were those carrier phases we used to compute the baseline? How did observations from a global network of tracking stations arrive at the control center? The latter certainly caught my attention since I was using the BITNET, the forerunner of the Internet, to supervise a graduate student in Maine, thus gathering my first experience with distance education.

My amazement with the science underlying GPS satellite surveying made me rush to establish a graduate course in GPS that fall at the University of Maine. The urge to tell the GPS story propagated into three editions of my book *GPS Satellite Surveying* and into the series of GPS-GAP Internet courses. As a faculty member, I have been wondering for a long time when we should stop recommending astronomy to our students to fulfill science requirements and alternatively recommend GPS, which is much "closer to home" and has such an abundance of science to offer. Of course, we no longer need the station wagon and midnight observations.

GPS-GAP has been designed as a cost-effective approach to education that takes advantage of the Internet. The courses are offered asynchronously, the class size is one (i.e., individualized instruction), and a course can start anytime. The time constraints of the traditional semester calendar do not apply. The courses can be taken in the workplace, at times convenient for the student, and at a pace that fits the needs of the individual.

Details about GPS-GAP are found at www.gnss.umaine.edu. The courses have been designed as one credit hour units, allowing the students flexibility in navigating the sequence of the courses and taking advantage of prior knowledge of the subject. The content of the GPS-GAP courses is closely tied to the textbook *GPS Satellite Surveying*. The material is presented with sufficient depth as needed for understanding all geospatial positioning accuracy levels, ranging from 100 meter to millimeter, in either real time or postprocess. Of course, such topics as ambiguity fixing, conventional and network real-time kinematic (RTK), Virtual Reference Station (VRS) networks, geometry-free solutions, and precise point positioning are included.

The current collection of GPS-GAP courses provides in-depth knowledge about GPS and the geodetic foundation. A new receiver antenna course and a tailored mathematics refresher course were recently added, and other courses are under development. An Internet browser is all that is necessary to take the courses. Computer-graded exams are available for assessment. The quiz questions play an important and integral part in the iterative learning strategy.

The asynchronous delivery of the material, iterative learning strategy, location independency of student and instructor, and focus on the individual student make GPS-GAP an exciting and scalable opportunity for students and professionals in surveying as well as GIS.

About the Author

Dr. Alfred Leick is a senior faculty member at the University of Maine, Department of Spatial Information Science and Engineering, Orono. He has been teaching satellite geodesy, including GPS, and adjustments since 1978. In 1996, he investigated procedures to combine GPS and GLONASS observations. That research is continuing and now also includes Galileo (the forthcoming European system). In 1990, he published the first edition of *GPS Satellite Surveying* (publisher: J. Wiley), with the second and third editions following in 1995 and 2004. He is editor-in-chief of *GPS Solutions,* a peer-reviewed quarterly journal published by Springer-Verlag, and he is a Fellow of the American Congress on Surveying and Mapping.

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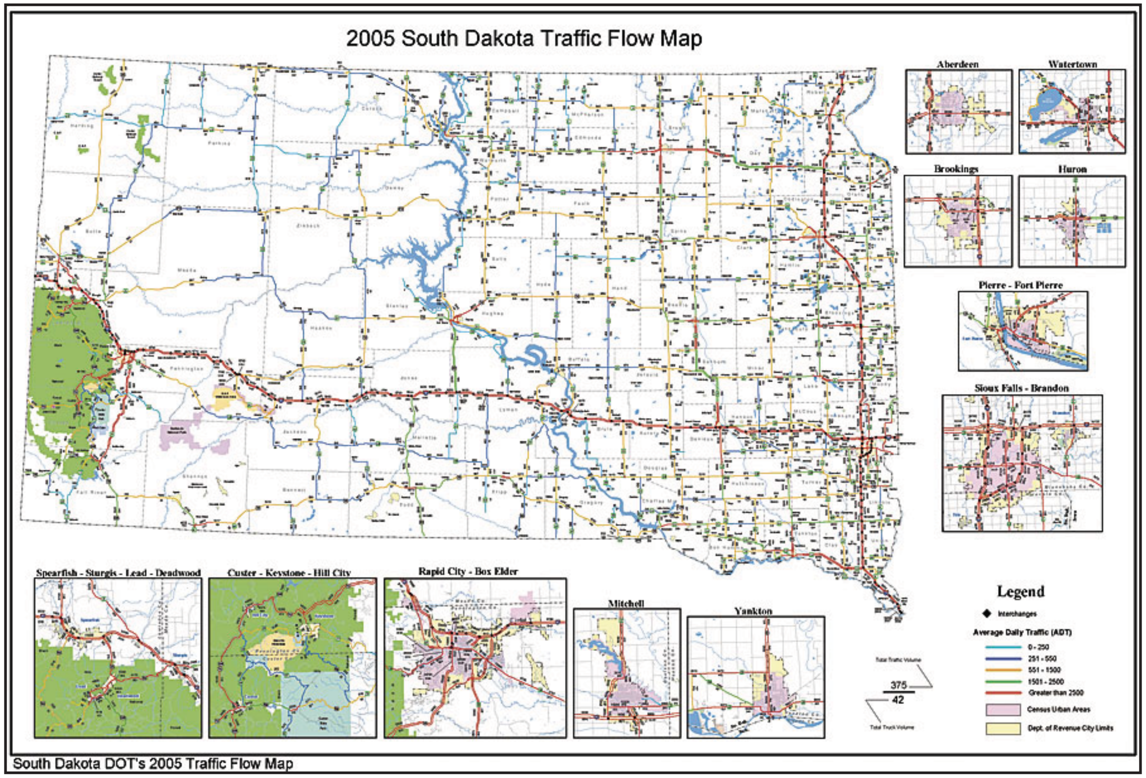
GIS and GPS Integration Eases Public Road Inventory

South Dakota DOT Sets New Standard for Data Capture, Storage, Updating, and Editing

South Dakota is the geographic center of the United States. Farmers there cultivate the same land their great-great-grandfathers did, but now with the help of geospatial technology on four-wheel-drive tractors.



South Dakota DOT's 2005 Traffic Flow Map.

It is just this technology that has allowed the South Dakota Department of Transportation (SDDOT) to accurately report local road miles, maintain an up-to-date inventory of local roads, provide updates for CAD-based mapping, and develop a dynamically segmented state highway system.

South Dakota has 83,000 miles of roads (serving 755,000 state residents). Of these roads, 7,800 miles are state, U.S., or interstate highways that are in the state highway (trunk) system. The remaining miles constitute 75,000 local, county, city, and township roads that are part of the nonstate trunk (NSTRI) system. GIS has been an invaluable asset to the SDDOT NSTRI program for the inventory and management of those local roads, along with map production and analysis of the state trunk system.

Step-by-Step History of Inventory and Management

Historically, several SDDOT lead crews were required to drive all state roads on a specific schedule to obtain and keep handwritten records of the physical features and surrounding attributes. These crews comprised SDDOT staff who drove the routes accompanied by various representatives of political entities to obtain records of change from previous collection cycles. Over the years, the number of SDDOT people associated with this process had declined for various reasons to the point where one staff person and seasonal employees could not perform the updates to physical features and surrounding attributes as needed.

The SDDOT NSTRI program started out using DOS-based GPS data collection and PC ARC/INFO. In 1995, the SDDOT Planning and Development District III and 1st District Association of Local Governments entered into contracts in which the districts would provide the manpower to use GPS to collect road alignments, attributes, and structures that the SDDOT needed to update its roadway inventory database and convert the GPS data into ArcInfo coverages. In 1997, SDDOT entered into the same type of contract with the Southeastern Council of Governments and the Northeastern Council of Governments. Roadway attributes to be collected included road name, surface width, surface type, shoulder width, shoulder type, city code, county code, parking configuration, speed limits, and DMI (the length of the roadway segment).

As ESRI technology has evolved through the numerical software releases, so has the SDDOT NSTRI program. Today's program uses ArcInfo 9.x Workstation and DOS-based GPS data collection. Some modifications have been made to the GPS data collection process to keep pace with the GIS. For the maintenance program, the planning districts supply SDDOT with yearly updates of ArcInfo coverages of roadway changes, additions, or deletions.

A New Standard

In February 2006, SDDOT's NSTRI program set a new standard of personal geodatabases as the environment for roadway data capture, storage, updating, and editing. To help meet the new SDDOT GIS roadway inventory program standard, the planning districts, as independent contractors, chose GIS Workshop, Inc., of Lincoln, Nebraska, an ESRI Business Partner, to create a customized GPS data collection interface for Trimble's GPS Analyst software. The GPS software uses hot keys, pull downs, and pick lists in GPS Analyst to create new roads and modify SDDOT roadway alignments in ESRI personal geodatabases. These tools populate attribute fields with SDDOT predefined choices.

The SDDOT roads data is being used by several private firms in the area, as well as several government agencies, including the South Dakota Department of Game, Fish and Parks' hunting atlas on walk-in areas; South Dakota Department of Natural Resources; the South Dakota Department of Revenue's sales tax revenue application; U.S. Census Bureau; U.S. Department of the Interior; and several South Dakota county GIS programs.

After 10 years, SDDOT views this program as highly successful. Now, as a maintenance GIS/GPS program, SDDOT receives yearly updates of road changes, additions, or deletions from the planning districts.

(Reprinted from the Summer 2006 issue of *ArcNews* magazine)

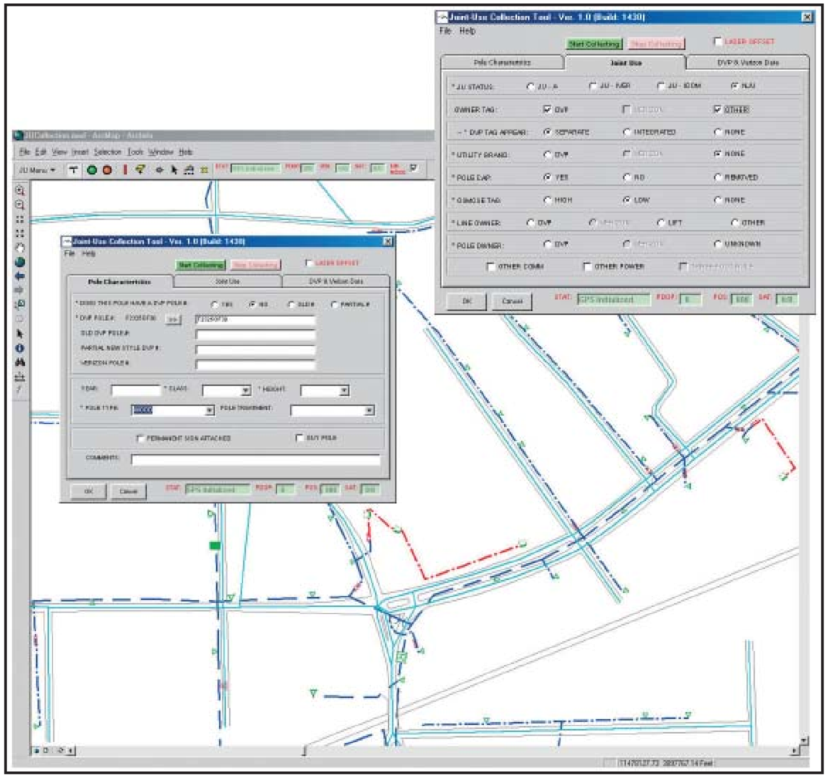
Dominion and Verizon Use Mobile GIS and GPS to Conduct Joint-Use Pole Survey

By Randy Trott, Timmons Group

Dominion Virginia Power and Verizon, two large companies providing power and phone service to their clients, share thousands of poles in their combined service territories in an effort to reduce the number of poles placed in the field. Utility poles are used to attach devices (e.g., transformers) and circuit lines. Some poles are shared and have attachments from multiple companies; in the utility industry, these shared poles are termed "joint use." Pole owners gain revenue by leasing space to other companies with the amount of revenue based on the number of leased attachments. Traditionally, it has been difficult to track pole ownership, attachments, and leasing revenues.

The federal and state mandates require periodic rate adjustments associated with joint-use agreements. Utility companies must maintain accurate records of pole ownership and joint-use status for utility poles in combined service areas. Pole inventories and attachments are very dynamic. Poles are highly susceptible to man-made and natural occurrences, and once damaged, they must be replaced. Other changes can affect pole-related data: overhead circuits are often rerouted or placed underground, and new commercial and residential developments require infrastructure growth, meaning more power and phone service. Many utility companies are using joint-use surveys to update pole ownership and joint-use status to meet standards and reporting requirements.

In the past, paper maps were used in the field as a guide for referencing pole locations as well as for plotting their location for future identification. Information was handwritten and converted to digital format in the office. This was a typical scenario before the introduction of mobile computers and GPS and GIS technologies.



This image shows the customized ArcView interface and joint-use collection tool. Inset: The joint-use collection tab.

In 2001, Dominion and Verizon contracted with ESRI Business Partner Timmons Group, a full-service GIS consulting firm headquartered in Virginia, to conduct a joint-use survey in their combined territories located throughout Virginia. Dominion and Verizon chose Timmons Group for its qualifications, including field crews, extensive experience with GPS technologies, and a geospatial applications development group needed to undertake this project. The survey consisted of collecting GPS coordinates and attribute information on 620,000 poles associated with 16,000 miles of service lines, using an average of 10 field technicians working at any given time. Timmons Group helped the two companies develop a method to collect joint-use and ownership data in an efficient and accurate manner. Data was captured and submitted as a final product digitally. This digital information provided a spatially enabled database and the framework for a GIS.

Timmons Group deployed a team of surveyors equipped with mobile pen tablets, such as the Fujitsu 3500. These systems were chosen based on their mobility, outdoor screen readability, Windows 2000 compatibility, and ability to interface with a GPS receiver using a standard RS-232 serial port. The Trimble PRO XR Pathfinder system was chosen to fulfill the GPS component because of its ability to collect real-time corrected positions.

Applications Development

A crucial component of the solution was a GIS-enabled asset inventory software application based on ESRI's suite of desktop applications. This solution needed to integrate with GIS and GPS and support multiple technicians collecting data in the field for long periods of time. The application component that was scoped, designed, and ultimately built allows users to view electrical devices, circuits, and other supporting GIS base layers. In addition, users are provided with a user-friendly interface to facilitate the collection of joint-use data. Data is captured in an ESRI geodatabase customized to meet the business requirements of both Dominion and Verizon. Poles, number, and type of attachments were captured for all joint-use poles. This facilitated the quantification of leasing factors for any given pole in the shared service area.

The joint-use collection application consists of a suite of asset inventory tools to enable field personnel to collect and store utility pole asset attributes and coordinate data collected using GPS. Visual Basic and ESRI's ArcObjects were used to build a customized common object model-based extension to ArcView. A joint-use toolbar was built to house collection, query, modification, and edit tools for spatial and attribute information. Trimble Pathfinder Tools Software Development Kit (SDK) and Visual Basic were used to develop the GPS interface. The GPS receiver component handles all communications between the GPS receiver and the application, including the configuration and supply of real-time differential corrections from radio beacons and satellites. Coordinate transformation and unit conversion components included in SDK were also utilized to convert the utility data collected into the Virginia State Plane projection. The SSF Writer component was used to customize the creation of an SSF file with unique point records that could be related back to the GIS data after postprocessing and differential correction. The application provided real-time status feeds into the ArcMap application within ArcView to display GPS information, such as position dilution of precision (PDOP), differential global positioning system (DGPS), and satellite availability and position collection directly onto the custom toolbar.

The Tablet PC Support for the ArcView extension from ESRI was utilized to achieve redlining and gesturing functionality. Tablet PC Support interfaces enabled functionality to be built, allowing the pen motion to be stored as Microsoft INK in an annotation feature class. Application users utilized this technology to draw, circle, and note assets in the field or identify potential problems during surveying. Other functionality was built into the application using Microsoft INK technologies to, for example, allow on-screen navigation through "gesturing." Users could draw a right arrow on the screen with a stylus. This gesture triggers the current view in the ArcMap document to pan to the right.

The user interface was designed based on a rule-based matrix enabling a "smart" application, which would disable attribute choices that did not follow the logic inherent in the decision matrix. This served to reduce the amount of human error associated with collecting important attribute information. Joint-use surveys typically require a high accuracy standard. This rule-base matrix approach allowed for a higher-quality end product while reducing the amount of postprocessing associated with internal quality control efforts. Prior to development of this tool, 12 to 16 hours per week were spent on quality assurance/quality control efforts.

With the correct hardware in place and a mobile GIS platform, a new method of conducting joint-use surveys was established for Dominion and Verizon. The ability to collect joint-use data and GPS coordinates in the field using mobile technology improved on old methods and now enables Dominion and Verizon to update and maintain joint-use data more effectively with the use of GIS.

(Reprinted from the Winter 2004/2005 issue of *ArcNews* magazine)

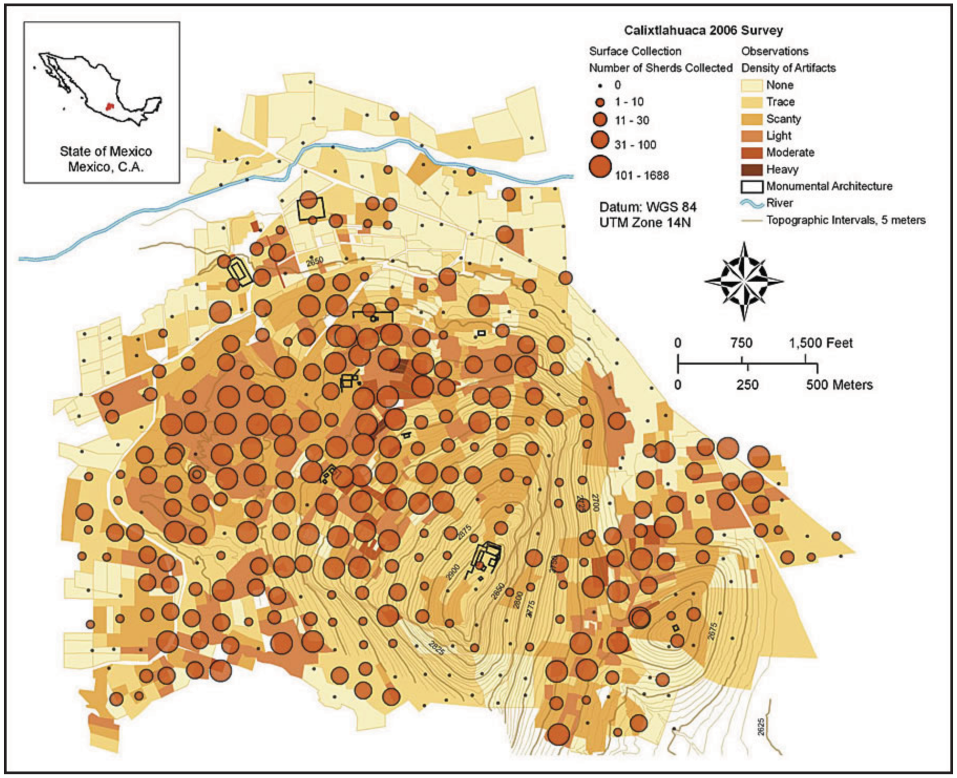
A Cost-Effective Approach to GPS/GIS Integration for Archaeological Surveying

Investigation Focus at Mexico's Aztec-Period Calixtlahuaca Site De-emphasizes Temples and Tombs

By Brian Tomaszewski, Ph.D. Candidate, Department of Geography, the Pennsylvania State University

Archaeological investigation often begins with systematic field surveys to inventory cultural features and artifacts visible on the ground surface of a particular site or region. These inventories are then used, in part, to gain insight into the overall spatial and temporal dimensions of a site based on artifact types found and to make decisions about which areas within a site will receive priority when conducting traditional ground excavations. Determining which areas to excavate is important not only for the underlying research questions of a given project but also for more pragmatic reasons, as most archaeological investigations are limited by financial and temporal constraints. It is with these constraints in mind that a cost-effective approach to integrating GPS technology with GIS was developed for an archaeological field survey in central Mexico. This approach allowed for the collection of accurate, reliable information about archaeological ground conditions, such as surface artifact densities, subsurface prehistoric structures, and natural features that could be integrated into and visualized with GIS for excavation prioritization and planning.

The field survey using this approach was conducted at the Aztec-period Calixtlahuaca site, located in the Toluca Valley approximately 40 miles (60 kilometers) due west of Mexico City. The earliest known occupancy of the site dates to approximately 1100 A.D. The site was occupied by indigenous peoples until its conquest by the Spanish in the late 15th century. The site has several pyramid or temple structures that were excavated in the 1930s by Mexican authorities.



Surface artifact densities at the Calixtlahuaca site collected with GPS (map by Juliana Novic, Arizona State University).

The team of investigators that conducted the survey are part of a National Science Foundation (NSF) grant to examine the nonelite residential occupancy of the site, a research approach that purposely de-emphasizes the investigation of so-called "monumental" structures, such as pyramids, temples, and tombs. A 4.2-square-kilometer systematic survey was conducted to find clues as to where houses and other nonelite structures were located, and the results of the survey will be used to prioritize which areas will be excavated in the following field season.

Earlier archaeological investigations at Calixtlahuaca focused on temples and tombs. Today, archaeologists are looking for evidence of where nonelite residents lived on the site.

ArcGIS Desktop (ArcView) was at the core of the geospatial solution developed for the field survey. In addition, Garmin eTrex Legend GPS devices were used for field data collection. These devices are easy to use and rugged; have large storage capacity; were accurate for the spatial needs of the field survey (within 1 to 5 meters at most control points when tested); and, at a cost of less than $200 per unit, were within the project budget. In addition, the free Minnesota Department of Natural Resources (DNR) Garmin Extension for ArcView facilitated eTrex Legend's GIS functionality.

This DNR program provided the key link to integrating GPS-collected data with ArcView. The program served as a bridge between the Garmin device and the GIS and allowed waypoints to be uploaded and downloaded from the GPS device, exported raw GPS data to shapefile and geodatabase feature classes, and provided functionality for synchronizing digital photographs with GPS waypoints to create hot link features.

All data collected was stored in a personal geodatabase, which was selected because of its native Microsoft Access file format (.mdb). This allowed spatial data to be integrated with nonspatial datasets that were developed in a standard Access database. Access data entry forms were quickly developed on personal geodatabase tables without any concern of damaging the spatial component of the data as spatial fields were simply left out of data entry interfaces. In addition, nonspatial data could be quickly and easily visualized in the GIS using join operations onto spatial data without any interoperability issues arising from trying to join data in different file formats.

The ArcView functionality proved essential to the project. An important data source used in the field surveys was digital orthophotos purchased from the state of Mexico. When the projection of these photos was found to not correspond with ground-truth data collected by the GPS devices, georeferencing functions of the ArcGIS Spatial Analyst extension were used to adjust the imagery, which after rectification and warping then matched correctly with the GPS data. Because of budgetary constraints, the crews used hard-copy maps in the field to mark relevant information. A critical component of these maps was Universal Transverse Mercator (UTM) coordinate grids displayed at multiple intervals. Field crews matched the coordinates from these grids shown on the paper maps with their real-time position coordinates shown in the GPS. This allowed the crews to stay oriented in the field and not waste time continually trying to figure out their position from the paper maps alone. A custom ArcObjects script was created to generate grid lines at user-defined intervals in a grid feature class layer that was used to generate these maps.

In conclusion, the use of ArcGIS Desktop coupled with a cost-effective GPS/GIS solution, ease of use, and integration capabilities of geodatabase technology allowed for the rapid development of a comprehensive geospatial solution to meet the needs of an archaeological field survey. By using this approach, financial and temporal constraints of the project were overcome without compromising the scientific integrity of the overall research goals. Although applied to archaeology, this type of approach could be used by any researcher who needs an integrated GIS/GPS/data solution but lacks the financial resources for an optimal solution.

About the Author

Brian Tomaszewski, a Ph.D. candidate and graduate research associate in the Department of Geography and GeoVISTA center at the Pennsylvania State University, has an M.A. degree in geography from the State University of New York, Buffalo. His research interests include GIScience, geocollaboration, historical GIS, and crisis management.

Surface artifacts collected and mapped in the field provide insight into where subsurface structures and other cultural features may lie.

More Information

For more information on this archaeological project, visit www.public.asu.edu/~mesmith9/Calix. For more information on the DNR Garmin Extension for ArcView program, visit www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html.

Acknowledgments

Funding for this project comes from NSF grant #0618462, Urbanization and Empire at the Aztec-Period Site of Calixtlahuaca, Dr. Michael E. Smith, principal investigator. Additional funding was provided by Arizona State University. The project also thanks the Instituto Nacional de Antropología e Historia (INAH) and the state of Mexico for their cooperation.

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Facilities Survey Feasible With GIS and GPS

By Mohamed El-Gafy and Yassir Abdel Razig, Florida State University

The analysis of existing facilities at the Florida A&M University (FAMU) Florida State University (FSU) campus in Tallahassee, Florida, is part of an overall campus planning initiative. The FSU campus plan addresses broad campus and environmental issues within the framework of the university mission and identifies specific facility improvements necessary to support existing and future programs. The existing facilities survey did not help management because it did not supply sufficiently current information on the condition and use of emergency phones and other campus facilities.

This article describes a data collection project that used GPS to furnish the current and correct data necessary to evaluate changes in allocation and configuration of facilities in the campus plan. This class project involved collecting data for emergency phones, fire hydrants, and manhole covers on campus utilizing the available resources at the university laboratories. This data was used to update the university database and will be integrated into a database that will serve as the foundation for a GIS system for university facilities.

The only qualitative criteria guiding the project were that the mapping software should be simple to use and would provide a starting point for GIS development and that GPS receivers would supply data of submeter accuracy or better. These criteria would allow for the development of facility maps sufficiently accurate for planning and management purposes, but not for use in design drawings.

The solution developed used three Trimble receivers, or rovers, to collect necessary field data in addition to a PC-based computer. This data would be associated with legacy data using ArcInfo.

Premission planning included accessing satellite positions prior to the fieldwork phase to ensure that the satellite geometry and availability would be acceptable and provide sufficient positional accuracy. The data required for this process was obtained from the Trimble Web site.

The team consisted of one graduate student and two senior undergraduate students. Training the team in the use of GPS receivers was simple. The original plan called for teaming each undergraduate student with the graduate student and supplying follow-up training as needed.

However, after collecting data for three or four points, the students were comfortable using the system and needed no further training.

With the help of the university facility managers, the team determined what attribute data would be collected. See Table 1 (below) for a listing of attributes collected for each type of feature. Once the fieldwork was completed, files from the receivers were transferred to the university computer using Trimble GPS Pathfinder Office software. Because field data was not collected using a real-time radio link, it was accurate only to approximately 100 meters. *[For an explanation of differential correction of GPS data, see "Differential GPS Explained" in the January–March 2003 issue of* ArcUser.*]* All positional corrections were made in postprocessing mode using Pathfinder Office. The software compares the satellite constellation used by the roving receiver for computing a position with the raw measurement data in the base file from each satellite in the constellation. Base file data was collected at known locations at the same time that field data was collected. Once the positional files were corrected, they were converted to a format suitable for export.

The data, in World Geodetic System 1984 (the default datum for GPS receivers), was added to a map created in ArcInfo and the files were reprojected into Florida State Plane FIPS 903. The university-legacy database files were converted to dBASE (DBF) file format and joined with the collected GPS data.

Layers containing the university-streets were added to the map. Satellite imagery of the campus was used to digitize the university building footprints and provide a background layer for the map. Adding these layers supplied context for the features that were collected and helped determine if they were optimally located. New features were added, bogus features removed, and most retained features were shifted slightly to more correct locations.

The facilities survey is now a management tool that provides use, condition, and budgeting documentation that will be used for facility planning and addressing deferred maintenance.

Fire hydrants	Year of manufacture (cast in the side of the hydrant base), make, general condition, the name of the street the hydrant faced, verification that the blue reflector was correctly placed in the street, and hydrant location
Emergency phones	The number on the phone (used as a unique identifier), color, appearance, functional status, and general condition
Manhole covers	Serial number, year of manufacture, make, general condition, the name of the street where the manhole was located

Table 1: Attributes collected for facilities.

About the Authors

Mohamed El-Gafy is a doctoral student in the Department of Civil and Environmental Engineering at Florida State University and is pursuing a research project that utilizes remote sensing and GIS technologies in civil infrastructure management and has completed course work in GIS.

Dr. Abdel Razig is an assistant professor in the Department of Civil and Environmental Engineering at Florida A&M University Florida State University. His research interests include GIS applications in civil engineering. He has a $100,000 grant to investigate the applications of technologies, such as GIS for infrastructure management, and has presented his research at many conferences.

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