The Changing Geospatial Landscape

Practically overnight access of terabytes of geographical information has changed the way we work, live and play. Instead of constantly being lost or fumbling around with paper maps we rely on a host of location based technologies on our desktop computers, PDAs and even our cell phones. These services fuel a market estimated at $30 Billion per year and represent a major IT growth sector. Today it is difficult to imagine a world without digital street maps, detailed aerial images or GPS technology. Imagine that you couldn't find an address or plan a route with MapQuest, Google Map or Microsoft Virtual Earth. Some serious golfers would really be handicapped without a GPS device that includes the layout of 21,600 golf courses and many anglers rely on their GPS to return to their favorite spot. Imagine that you couldn't use Google Earth to fly to any place on the Earth and conduct a virtual tour complete with videos, photos, news articles and web sites for hotels and restaurants. Or imagine that you were searching for a new house or trying to sell yours but did not have detailed air photos, locations of property for sale or houses that recently sold. Imagine that you did not have a satellite navigation system in your car when visiting a new place - a world without Garmin, Tom Tom, Never lost, or On-Star. This world existed only a short time ago.

While geographically enabled technology is now embedded in our daily lives most users have no idea how recent the technology is, the science behind it or who to thank for it. These mainstream commercial applications have emerged by taking advantage of investments, innovations and policy decisions supported by the federal government over the past thirty years. These innovations include everything from the internet, to communications infrastructure to detailed digital mapping, to better modeling the earth's sphere to the creation of a constellation of Global Positioning Satellites (GPS). Only through enlightened public policies have these investments been freely shared and therefore fostered a robust commercial market that extends around the world. For the continued benefit to society, it is incumbent upon the nation's policy leaders to understand the government's role creating these services, how much the landscape has changed over the past 30 years, and what they can do to ensure continued advancement in geospatial technology in the future.

A brief history of major events; digital roads, GPS and location awareness

The detailed street maps that today support web based mapping applications and in car navigation systems can be traced to the innovations made by the Census Bureau about thirty years ago. Its initial decision to begin to create digital street maps to support the 1970 Decennial Census has now evolved into two multibillion dollar European Companies. The initial experiments were expanded in the mid 1980s when the Census Bureau teamed up with the US Geological Survey to generate the first nation wide digital street map with address ranges. This became the TIGER system that supported the 1990 Census and forever changed the way we interact with maps. In 1996 MapQuest utilized these intelligent street maps to build a web based system that could determine the geographic location of a street address and display in on a map. MapQuest was an over night sensation that received 1 million hits in its first 30 days (now 40 million / month). The sale of MapQuest to AOL for $1.1 billion in 1999 represents a landmark in the evolution of the geospatial technology and marks the date when location based services officially became part of mainstream internet business. The need to keep street maps and addresses up to date resulted in the creation of Geographic Data Technology and Navteq which have recently been acquired by European companies. GDT was initially purchased by Belgium company TeleAtlas in 2004 and is now being acquired by Tom-Tom a Dutch personal navigation supplier. Navteq has been purchased by the Finnish telecom giant Nokia for eight Billion dollars. The fact that a major telecom company would place that kind of price tag on geospatial data demonstrates the value of these assets and points toward further vertical integration of location based services especially on cell phones and pdas.

While detailed digital street maps provide the basis for spatial search and navigation they do not help you know where you are. This task is handled by another American innovation the Global Positioning System, or GPS. GPS was designed in the mid 1970s to support U.S. Department of Defense missions. When the 24 satellites that form the GPS Operational Constellation were established in the mid 1990s we had a revolutionary system that could determine geographic coordinates without reference to any landmarks or features on the Earth. By recording signals from at least four of the satellites these GPS receivers were able to determine the X, Y and Z coordinates of the receiver anywhere on the Earth's Surface or on an aircraft. In fact, since 2000 almost any GPS receiver is able fix a location within a few meters of its actual location. [1] At the same time, the accuracy of GPS signals can be enhanced by a network of highly accurate land based survey stations that provide precise coordinates required for surveying. It should also be noted that this system only works because we also developed a highly accurate model of the shape of the Earth. A series of enlightened federal policy decisions opened this military system to commercial applications and has spurred a huge new commercial market around the world. As a consequence of these decisions creative entrepreneurs have coupled these incredible and inexpensive tools to build hundreds of applications that support the public's insatiable appetite for location based information.

As the cost of GPS receivers has plummeted the range of applications has skyrocketed. The personal navigation systems manufactured by Garmin, Tom-Tom and others represent the integration of digital maps and GPS technology. The demand for navigational assistance has been at the forefront and has been a major boon to car rental agencies. Furthermore, inexpensive personal navigation systems that cost a few hundred dollars have become a popular consumer items that are small enough to fit into a Christmas stocking. Other systems go a step further by interacting with you to check on your status or to provide real time information about traffic conditions. While this enables you to know where your friends are it also provides a basis for others to track the movement of the device. This tracking capability is now widely deployed to follow the movement of children, pets, fish, employees, criminals, or vehicles. For example "PetSafe" sells a GPS dog collar for $150 that enables the owner to track their pet's movement for $16.49 per month!

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1. In addition to A-GPS, iPhone 3G uses signals from GPS satellites, Wi-Fi hot spots, and cellular towers to get the most accurate location fast. If GPS is available, iPhone displays a blue GPS indicator. But if you're inside — without a clear line of sight to a GPS satellite — iPhone finds you via Wi-Fi. If you're not in range of a Wi-Fi hot spot, iPhone finds you using cellular towers. And the size of a location circle tells you how accurately iPhone is able to calculate that location: The smaller the circle, the more accurate the location.

Since this technology is barely eight years old it would be useful to catch a glimpse of the future and to understand why Nokia and other telecoms place such a high value on accurate geographic information. Geospatial technology is embedded in the next generation the way email has become ubiquitous to this generation. Perhaps the best window into the future is provided by the Apple IPhone that has an embedded GPS receiver into a device that can wirelessly access the internet anywhere in the world and integrate its location with both self contained and web accessible applications (Think about MapQuest on your cell phone with a symbol marking your current location.) Once one can fix their location and transmit it to others a full range of applications is possible. These include location based services (find the closest AMT), advertising (a coupon for a discount at a fast food restaurant around the corner) or social networking (are any of my friends nearby?). The fact that other people can follow your movements (geo-tracking) with or without your permission or knowledge leads to list of reactions – that range from comfort, to convenience, to reluctant acceptance to outrage. In fact, some academics have equated geo-tracking to “GeoSlavery”.

The ability of individuals to accurately determine and record locations in the field is also revolutionizing the way geographic data is collected and compiled. Using GPS enabled devices thousands amateur users are routinely creating hordes of Volunteered Geographic Information. For example citizens in New Jersey are locating and reporting wetland features. Owners of personal navigation systems are now able to act citizen sensors to inform their vendor about changes in road features and points of interest. Clearly the most extensive example of how volunteered geographic information can change the traditional way geographic information is created is “Open Street Map”. This is a world wide phenomenon that has enlisted thousands of volunteers who often form mapping parties to create their own street map. Therefore, in a manner of about three decades the entire concept of maps and how they are produced and used has changed. At first traditional paper maps were traced by public agencies to produce digital versions. These digital versions where then maintained by commercial companies and distributed over the internet, or on CDs/ DVDs or on personal navigation devices. In many parts of the world maps are still considered military intelligence therefore, the best or only map that may exist has been created in the field by volunteers riding bicycles or walking. Furthermore these maps can be freely downloaded at openstreet.org.

The Evolution of GIS; from Institutions to Virtual Globes

While the origins of geospatial technology actually spans several centuries the digital version began in earnest in the 1970s with advent of the first tools that could convert existing maps into digital data. These early systems ran on large mainframe computers that only existed in large public organizations. In the US the period was dominated by the federal agencies such as the USGS and the Census Bureau that developed their own software to basically create and maintain a digital representation of their existing paper maps. However, in addition to map generation these systems were used to conduct inventories of land use and some integration with other layers of information. Pioneering work by the Census Bureau even developed a system to automatically assign coordinates to a street address (Geocode). Furthermore, by 1980 some innovative firms especially ones closely tied to natural resources such as timber, a few state agencies, large local governments and utilities were operating their systems on dedicated minicomputers. In fact, a 1980 NRC report on the Need for a Multipurpose Cadastre suggested that there were no technical issues to prevent the creation of an integrated nation wide GIS to handle millions of tax parcels.

The decade of the 1980s represented a migration of GI technology to affordable integrated graphics workstations and client server environments which facilitated the sharing of data across a network. This enabled the technology to be adopted by hundreds of midsized organizations and agencies. These organizations often relied on medium scale digital data bases that had been created by federal agencies. These data sources supported applications based on relatively crude scales such as street centerlines and administrative areas and land use. Tremendous inroads were made in the use of multiple layers of data for planning applications, suitability analysis, reapportionment and other census based data. Using commercially available software tools from companies such as ESRI and Intergraph organizations began to create and maintain extensive geographical databases of corporate and public assets. Most of the analysis consisted of projects that addressed specific issues rather than the daily business activities of an organization. These projects were performed by skilled technicians who knew how to find and use the proper set of software tools and the output was often a printed report with tables and maps. Dramatic advancements were made in tools to handle images and models of the terrain. Commercial digital image processing tools from companies such as ERDAS could convert aerial convert aerial photographs into geographic data however advancements in direct capture of digital photography was limited and satellite data was only useful for large scale reconnaissance of activities such as agricultural production.

In general terms the decade of the 1990s represented a watershed in the democratization of computing and GIS along with it. GIS software migrated from UNIX to Windows operating systems and from specialized work stations of common personal computers. Software was accessed through easy to use graphical user interfaces and performance improved as the industry provided faster and cheaper processors, graphics cards and storage systems. This advancement meant that powerful GIS software could be accessed not only by technical "chauffeurs" who created projects but rather directly by decision makers, planners, scientists and students. Consequently GIS was successfully adopted by thousands of local governments and businesses. Ready and free access to digital version of Census TIGER files and USGS topographic quadrangles provided a fundamental base map across the nation. Universities were able to establish teaching labs and helped to train the labor force. By the end of the decade personal computers were linked to internal networks and the internet. These advancements allowed for innovations such as MapQuest that could be accessed by average citizens without any training or additional cost. The era of location based advertising emerged. Commercial GIS software expanded to include hundreds of tools to integrate different kinds of information, process images, perform site analysis, support decisions and generate high quality cartography. GIS software could incorporate digital imagery and Computer Aided Drawings (CAD) and it could generate publication quality maps. Satellite imagery with 15 meter resolution was also widely available and GPS technology was changing the way surveying and earth measurements were performed.

The 21st century marks a period of widespread adoption and public Use. Most of the technical issues have been resolved and fast affordable computers with almost unlimited data storage capacity make GIS a practical and affordable tool. The range of applications is limitless and includes realistic three dimensional visualizations and integration into standard data bases that enable a geographic perspective on almost every possible information domain. Some experts suggest that emphasis shifted to the technical and institutional infrastructure to support GI throughout society. The term spatial data infrastructure emerged. In the United States this actually began in 1994 when President Clinton issued an executive order to create the National Spatial Data Infrastructure and formed the Federal Geographic Data Committee. These efforts acknowledged that GI was a big business and that it needed to be better coordinated and less redundant. (How many versions of street centerlines do we need?) The emphasis shifted away from products to "processes, knowledge infrastructure, capacity building, communication and coordination". In an internet based world it was not good enough to share data but there was a need to judge its quality and to determine its fitness for use. Therefore, it became important not just to produce and share geographic data but to document it like one would in a library's card catalog. The quality and content took on a different meaning as public agencies published their data on web browser applications that allowed average citizens to query and view detailed information about their property.

While there has been a steady growth in the use of commercial software operating on desktop computers to create and maintain detailed data across all levels of government and private sector businesses there has also been an emergence of "open systems" and open data standards. These developments have opened the door to a new market for customized applications often to support executive decision making or simply to meet the needs of the casual user. These applications were built not on procedural languages but rather empathized reusable components developed with object oriented and scripting languages. With the advent of huge server farms spread across extensive networks there has been a new emphasis on server side computing where data and images are stored on a transparent cloud and GIS processes are performed on demand on remote servers. Rather than maintaining large staffs and infrastructure firms can now build entire applications without purchasing or storing any data or large tool kits.

Much the emphasis on the 21st century has been placed on providing accurate data to support decisions. In the public and commercial arena these decisions can range from how to pursue an enemy on a war field, what are the best land use alternatives for combating global warming, where to allocate police to reduce crime, where there are areas at risk for West Nile Virus, where are we going to build new schools or locate landfills or how did route a fleet of delivery trucks. At the same time the average citizen wants to know how to get to a party, where to vote, whether to buy a specific house or where to find your friends and will the ambulance find them when they call 911. .Since these citizens are also taxpayers and homeowners they have an entirely different set of needs and expectations than GI users of thirty, twenty or even eight years ago. They access this information at home though powerful inexpensive personal computers across broad band networks. They are as interested in publishing as they are about consuming (e.g. Facebook's "what are you doing now feature"). They are often armed with their personal navigation system, are regular users of Google Earth and they expect to "see their house" in terms of its use and value. They flock to sites such as Zillow.com and Cyber homes.com to view the value of their property and what the trends are in their neighborhoods. They also expect to be able to link to their local assessor's records. They expect detailed recent aerial photography – even better with a "Bird's Eye view that includes four different oblique views. In reaction to

these demands local governments are embracing GIS into their enterprise wide IT environments. In fact Waukesha, Wisconsin reports that there are scores of business decisions relating to everything from E911 to school zoning are driven from a parcel based GIS because it is the expected norm.
Things change dramatically when designing to meet the needs of users who are homeowners and taxpayers. As Governor O'Malley of Maryland recently stated

> …I'd like you to consider the answer to this question – why is it that virtually any display of GIS technology quickly inspires someone one to ask the timeless question, "…Can you show me my house?",…
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> Through the power of mapping, we were able to create our city's [Baltimore] first-ever complete inventory of housing stock including the ownership information that could be used and accessed by mangers of boarding and cleaning crews, by those responsible for policing, those responsible for inspections, those responsible for filing the lien on the property after cleaning, those in the city's housing department responsible for clearing title, and taking title, and those responsible for disposing of title so the property could be redeveloped and returned to the tax rolls.

In order to meet these new user expectations – citizens, public employees, real estate associated professionals – a unified approach is required. Property lines must be accurately depicted, images must display fine details (new additions and renovations), and terrain models must model the flow of water throughout a neighborhood. These needs can only be met by investments in new data and GI tools that can integrate vast amounts of very high resolution data that often measures in terabytes.

The Evolution of GIS; the new white board

The previous discussion suggests that the evolution of geographically information (GI) technology into mainstream consumer applications had its origins in investments and innovations made by the federal government. In the beginning of this transformation, a single or sometimes a small group of scientists could post information into a single computer and see some results. The barrier still existed for that group to publish results to a wider audience. Now, however, the current IT infrastructure has migrated to a federated web based and private sector approach. This changing landscape both impacts and is impacted by multi-collaborative stakeholders; not just the federal government. The shift has come about because of significant advances in technology over the relative roles of different stakeholders in the current environment. In other words, how does the fact that Microsoft, Apple and Google have recognized the business case for location based searches and applications changed the playing field?

The Earth is a huge study area. It can be divided into pieces of various sizes and studied at macro scales or micro scales. For some applications such as tracking hurricanes scientists can rely on relatively coarse grained information but need it updated in real time. Conversely, a civil engineer may require centimeter level precision when constructing a new bridge. The history of GI applications had been one of making tradeoffs – one could either study large areas at crude levels of detail or small areas in fine detail. As we approach the end of the first decade of the 21st century these tradeoffs no longer apply. Perhaps no application exemplifies the success of this better than Google Earth. When released in June 2005 Google Earth represented a paradigm shift that shook many of our established perceptions about geospatial data. It offered multiscale, full earth visualization that was free, easy to use and provided a dynamic sense of travel. While several examples of large scale robust geospatial databases existed none could match Google Earth's ability to fly virtually to anyplace on the Earth and visualize information at fine detail. That fact that it was free and easy to use led to its instant success that has sky rocked over the past three years as content from scores of sources (National Geographic, New York Times, You tube etc.) has been geographically tagged. A recent article "Armchair Archaeology" in *The Economist* describes how Google Earth is changing the way archaeologists "make discoveries, develop theories and plan expeditions". As one of the archeologist's states "Google Earth gives you free access to imagery that would otherwise cost a fortune and require specialist training to make use of". While it is hard to accurately estimate the number of Google Earth users a conservative estimate would exceed 100 million. The net result is that in just three short decades, the number of GI users has grown from tens of thousands, to a few hundred thousand and then almost instantaneously jumped to hundreds of millions. The impact of Google Earth has been widely documented in the popular press by experts such as James Fallows of Atlantic Monthly who considers GE to be the fourth major innovation in popular computing (along with text editing, the internet, and the web). It is so popular that it has been the subject of New Yorker Cartoons and has its own "Dummies" guide. More importantly, it has actually become the preferred platform for hosting and sharing geographically referenced content of all kinds. In many ways GE has emerged as the new whiteboard, with 100s of millions of users posting, consuming and comparing data collaboratively on a common earth study area.

Considerations amidst the Sea Change

The Geospatial Information and Technology Association reported that the geospatial sector has steadily increased by 35% a year, with the commercial side growing at an incredible rate of 100% annually. The US Department of Labor predicted that the geospatial was one of the three technology areas that would create the most jobs in the coming decade. All of these changes in terms of users and expectations have turned the traditional governmental and commercial relationships up side down. Most noteworthy has been dramatic shift of the federal government from being the primary provider of geographic data to that of a major consumer. With a few exceptions for administrative regulations such as the decennial census and flood plain boundaries local governments create their own data from in house resources or commercial providers. In times of emergency the federal government must acquire the most detailed and current data from these local governments. With companies such as Microsoft and Google as customers, commercial data providers – Navteq, TeleAtlas, Pitney Bowes, First American are doing a brisk business. There is also an insatiable demand for high resolution imagery – from both aircraft and satellite platforms. In fact, the recent launch of GeoEye-1proivdes a glimpse of the new relationships between private and public organizations. This satellite based camera is capable of collecting black-and-white images with a 0.41-meter ground resolution and 1.65-meter color images. The major customers for these images are the National Geospatial Intelligence Agency and Google. Closer to Earth there is a robust competition among aerial photography companies that can put fleets of aircraft in the air with sophisticated digital cameras that can capture and transmit huge quantities of geographically registered images – billions of pixels as small as a few inches. Other interesting examples include Pictometry's data that provides 4 inch pixel images from five viewpoints. These images have added a new dimension to applications such as Microsoft's popular Birds Eye View that provides a whole new perspective on house hunting. Another major shift in data collection relates to the use of airborne lasers to collect detailed elevation data. These lasers have been characterized as the equivalent of sending thousands of surveyors into the field to collect X, Y and Z coordinates. As a result it is possible to increase the accuracy of flood plain determination and the potential impact of sea level raise in coastal areas.

The relative shifts in data production from federal to local levels call for new forms of partnership and raise serious questions about data sharing agreements. When the federal government was the primary data provider it was regulated by polices that required data to be placed in the public domain. This policy jump started an entire industry and led to the adoption of GIS capabilities across public and commercial sectors. However, these arrangements are very different when data assets are controlled by private companies or local governments. For example, when updating the street networks to prepare for the 2010 Census the Census Bureau could not take advantage of the existing commercial data from Navteq or TeleAtlas and has spent hundreds of millions of dollars to develop a duplicate version of street centerlines. The Bureau which pioneered the field has attempted to assemble street network data from more than 4,000 local governments. They have often found the data do not existent, are incompatible or unavailable due to local licensing policies. A similar situation exists with respect to the federal government's need for tax parcel information. Critical information about the use, value and ownership of property is needed by FEMA, the Forest Service, HUD for emergency preparedness or response at times of hurricanes or wild fires – or even to monitor the current mortgage mess. Unfortunately there are no arrangements for the federal government to acquire the detailed property related data that it needs to make appropriate decisions. The irony is that private companies such as Zillow are often better prepared that the federal government to support these critical decisions.

While there has been a shift in the relative roles of the federal and local governments state governments have emerged as increasingly important intermediate level of GI coordination. In fact, the National States Geographic Information Council (NSGIC) represents one of the most active forms of Spatial Data Infrastructure and almost every state now has a state coordinator. NSGIC has an active agenda and is working closely with the FGDC – for new initiatives such as Imagery for the Nation that is a model for new partnerships in which the federal government provides partial funding for local governments to acquire high resolution digital imagery – that would be collected by commercial data providers.

We recognize that nearly all the data, technology and applications we see today, can be traced to innovative policies and government practice of the past. As such we require similar innovative policies now to keep pace with this remarkable sea change. Government based GI can no longer think of itself as a player outside of or immune from private sector, state, local or even public stakeholders. In many cases these stakeholders have embraced technology and processes which have rapidly outpaced anything the federal government can provide. At a minimum, what is needed is a commitment to better spatial data, recognition of the multi-stakeholders place in this brave new world, and coordinated investment. While it is fascinating that we have millions of hits on Zillow, rental cars with navigation applications, and phones with location based services to locating friends, the true value of the spatial data infrastructure still lies in illuminating complex policy problems. If we really want to solve global warming, sea level rise, affordable healthcare, homeland security foreign oil dependence, then we need the next set of innovative policy fostering in a dynamic and robust spatial data infrastructure; something that was promised over 15 years ago.

The need for new partnerships and governance that include public and commercial interests has resulted in the formation of the National Geospatial Advisory Committee. This new committee of 28 experts from all levels of government, academia and the private sector has been formed to:

> The Committee will provide advice and recommendations related to management of Federal and national geospatial programs, the development of the National Spatial Data Infrastructure, and the implementation of Office of Management and Budget Circular A-16 and Executive Order 12906. The Committee will review and comment upon geospatial policy and management issues and will provide a forum to convey views representative of non-federal stakeholders in the geospatial community."