GIS and Ground Control; an Inescapable Dependency

On November 4th, 1922 an utterly remarkable and now world renowned discovery was made. Archaeologist Howard Carter, under the sponsorship of the Earl of Carnarvon, found the first undisturbed royal burial in the history of digs in Egypt's Valley of the Tombs of the Kings west of Luxor. Carter had been digging more or less continuously for fifteen years of digging seasons grasping at tiny scraps of evidence to fuel his belief that the tomb of a little known son of the heretical Pharaoh Amenhotep IV (Anhkenaten) was in the Valley and as yet undiscovered. Carter was immensely experienced and comprehensively prepared. And if he was not prepared for the sheer magnificence of what he found, he was certainly prepared to document and deal with the burial site of Tutankhamen. Among his preparations was to retain the services of both a professional photographer, Harry Burton and two gifted draughts men, Hall and Hauser. The science of photography was very well established by this time and a good deal of work in terrestrial photogrammetry had already been done both in the fine arts (perspective) and site measurement (engineering). Carter's interest in including both drawing and photo imagery sprang from an insight we can use today. He had a realization that technical photography and draughtsmanship were complementary. Art and science met and a versatile, detailed and complete visual record of an unparalleled historic event was made. In the process this truth was highlighted, superficially similar records of objects, places and processes, made with different methodologies often contain complementary information that cannot be obtained from one method alone.

A photo and a drawing, even if we avoid discussing purely artistic issues, are not the same thing. The abilities of the mind's eye are far different than the sensitivities of silver nitrate to light or, in a more recent technology, photons of light falling on a sensitized surface to create pixels of reflective value.

It is not a large stretch to consider GIS technology and land surveying in the light of Carter's insight about the values of different technologies in observing and treating what is essentially the same material.

For our own purposes let's extend Carter's insight to say that a GIS is not a cadastre and vice versa. Both contain similar elements and in current circumstances there may be considerable overlap in function and even creative origins. One basic and very significant difference is that a GIS is wonderful at presenting data in a very large and diverse context. Much of the energy and value of the GIS derives from its ability to depict and analyze vast amounts of data from manifold sources, legal mandates and purposes. Land surveying is often more specific, more absolutely accurate and devoid of explicit efforts at analysis. Unlike the GIS a very detailed and precise legal protocol governs the final output products, and, for a client, the deliverables. Ultimately, however, the GIS and the survey are intended for different uses, or, are they? Through the progress of this talk we will look closely at that question and the relationship between the two disciplines.

The subject we are approaching is less technical than it is essentially philosophical and cautionary but optimistic. Almost all serious and complex endeavors have elements that are straightforward and those that are not so clear. Much GIS technology surfaces in the form of an "expert system" which is self-contained. In some contexts of use this is very nearly true but in others it is not nearly close. Establishing or utilizing a local base map or controlling environment for a GIS is one of those areas in which the user must add insight and understanding on a rare level in order to obtain success even in the presence of the expert system.

Some of our all too brief discussion here will lean toward an understanding of the differences between art and science; between that which can be quantified and that which results from informed judgment and experience. Technology only has the appearance of being objective and not subject to multiple interpretations or possibilities. The reality is that what appears to be impartial science is often most productive when it is guided by practice, history and even intuition based on many applications of technique in diverse circumstances.

California's body of GIS Professionals and Professional Land Surveyors both deeply depend on accurate ground control to develop the products for which they are responsible. Exploration of how control is understood and employed in both disciplines can be fruitful in advancing the goals of both sets of practitioners and may yield a model for coordinated efforts on a new and more productive level.

To facilitate our discussion we will consider two signature products associated with these respective professional bodies; the Record of Survey (RS) and the GIS feature class. How do these models of conditions on the ground generally come into existence?

The Record of Survey is relatively straightforward.

A need to clarify a land base circumstance is discerned. This may be the direct desire of a client, it may be necessitated by a legal requirement or it may anticipate further work in a given location. By investigation of preexisting public records, the examination of conditions and evidence in the field and the measurement of distances, angles and vertical references in the field, a basis for the new document is created. As you know, a great deal of the measuring activity is today done with the benefit of GPS. This is an important topic to which we will return. The conditions for the creation and public filing of such a document are highly regulated. If you choose you may wish to examine the rules in the Land Surveyor's Act portion of the California Professions Code; Article 5 Section 8762ff. The fundamentals are to dig deep, both in the Recorders Office and in the field, measure and calculate diligently; follow good practice and observe the mantra associated with many small businesses "Location, location, location!" But the Record of Survey is also a highly interpretative document which depends on an understanding of local positional history as much as intensive field investigation. A sense of judgment based on experience is also critical to creating such work in a timely and comprehensive fashion. For these reasons when the RS becomes part of the public record it will help tell people not only where things are but how they came to be and all of that with a high degree of confidence.

How does the GIS feature class come into existence? This is a far more complex and variable circumstance; little regulation is involved and there is some disagreement over the nature of good practice and due diligence in this regard.

One of the simplest ways a dataset may become available for use is that it may be shared or sold by original creators, vendors or otherwise, or passed on by middlemen and acknowledged as the work of others.

GIS feature classes are often shared among users and developers. Sharing out data is one of the chief values of a GIS as it theoretically enables those most responsible for the substance of a feature class to create and maintain it and then act as an informed source by way of metadata and historical understanding of the feature's development and descent. There are two important points here. We have as yet not answered the questions of the features class's ultimate technique of creation or its factual origin but we have acknowledged that a feature class is often a very public resource which moves beyond its creators in some dynamic and occasionally highly embarrassing ways.

A further difficulty with shared data arises from the fact that the associated metadata is often incomplete, inadequately explains the spatial origins of the dataset or is poorly understood by the ultimate user. This can be easily labeled bad practice but it is nonetheless commonplace among distributors. And, on the receiving end, the need for the data often overpowers any requirement to be circumspect or even cautious about the source methodology.

Probably the most common classic method for creating a GIS feature class is table or heads-up digitizing. The former process is normally conducted from paper originals and the latter from scanned and geo-registered images of the paper or Mylar originals. Everyone who has worked in the GIS field for any amount of time is familiar with the almost inevitable failures and pitfalls of these methods. Originals are often poorly scaled, inaccurately constructed, "stretched" from their original dimensions or incomplete. In addition, scanned images may possess substantial image "noise" which may prove difficult to separate from the meaningful information in the scan.

Also as a subtext which we shall encounter again, moving from vector to raster and back again can introduce subtle errors based on pixelization. Depending on the fineness of units and subunits model of the design plane and the resolution of the image, locations of corners may be moved to the nearest pixel which may deform the actual geometries being recorded into the feature class. This is not to mention the fact that digitized and scanned documents are notoriously difficult to integrate from session to session across the desired coordinate plane.

Another common method of developing the GIS feature class is more rigorous and direct and consists of constructing the elements from record documents. These documents might be legal descriptions, engineering plans, records of survey, parcel maps, mapping exhibits (both published and unpublished), and field and journal notes. While this method presents a far higher possibility for accurate results it makes certain demands of the user. A GIS professional who seeks to use these sorts of documents must be proficient in understanding the technical language of the documents of land management and be knowlegible within the process of the recording and publication of such documents within the public realm. In addition, feature creation based on the land documents must have a sound model of the local coordinate system (probably the US Public Lands System) as a basis of locations and bearings. Also a full understanding of mapping projections and the translation of coordinate systems will help to head off potential difficulty.

A third method for creating features which is less commonly used but can be appealing in terms of cost of generation is to utilize digitization or raster to vector conversion from a base map of rectified orthoimagery. The USGS pioneered such imagery but the elements offered were static for long periods of time and were of quite low resolution. The really broad use of satisfying, high-resolution imagery is the result of consumer demand for contemporary (nearly instantaneous) and extensive ortho images which have lead to a cornucopia of "off-the-shelf" image materials. No longer tied to expensive and confined contract image runs many users have availed themselves of large areas of digital imagery in which very tiny features may be observed. However, once more there is a need for real understanding of the raster to vector problem but more basically of the science of photogrammetry. Much commercially available imagery is created with the general user in mind. Often the details of capture and rectification are not known or understood by the user and in some cases are not disclosed by the vendor as they are considered commercial secrets.

A subset of this sort of feature creation is to contract with a vendor for photogrammetric analysis of imagery to directly create feature classes by gathering plan from imagery models within a plotter system of some sort. Advanced systems involving radar, LIDAR and digital photogrammetry are often used to identify and locate valuable GIS features such as building footprints. This method has the advantage of dealing with image distortion and displacement by eliminating them in the controlled model and, since models must be initially set up, minimum levels of control are required to begin with.

Finally a GIS feature class may be created by field measurement and collection of data. Here is a place where the arrival and refinement of new technologies has created a unique opportunity. Plainly anyone of reasonable intelligence and technical aptitude can go into the field and make relatively refined and dependable measurements of location. Why is that so? What separates current locational technology (specifically GPS) from the classic methods of positioning? Historic control surveys depended on a laborious extension of existing ground control into the area of interest. Original bases of bearings and coordinates were established by observations of stellar bodies and sometimes the sun. This technique was a refined form of the methods previously used in deep water stellar navigation. But modern GPS units contain an inherent basis of bearings established by contact with the constellation of satellites which support the GPS. There is no need for extensive reduction or refinement; context is instantaneous.

In this situation there is, however, once again, a great burden on understanding, training and insight placed upon the user. Some questions that arise are what is the intent of the state plane systems? Are there distortions and losses in moving from geodetic to plane coordinates? Is the user able to confidently identify control points in the field as those that are sought? How effective are those measuring in the field with the designated instruments?

Most modern consumer GPS instruments are self-contained “expert systems.” A handheld GPS is one of the wonders of our technological world. It allows virtually any user to identify their location and map it in a way that can quickly become a GIS feature class. Together with the support of an output of differential GPS signals such as the FAA’s WAAS or in other parts of the world the EGNOS or MSAS system can consistently bring handheld results to less than ten feet. But any GPS system is not, of itself, expert enough to deal with the sort of information that is supported by the space vehicle almanacs or merely in the signal information base. Long term and short term clock and orbit errors, IONO correction grids and data integrity info situations can all degrade satellite results in ways that may not be obvious to the user for some time.

The upshot of our review of the major GIS feature development methods is a series of questions that the user would wish to ask. Do you wish to spend your time and energy developing the necessary control or doing actual first tier GIS activities? What is your budget for establishing control and field checking that control and the feature elements that you develop from it? If you are using state plane projections what is your plan for migrating through changing datums and the more frequent changes in control epochs? And finally, if you are using control which you have purchased or otherwise obtained, what is your experience with error theory and correction. If you choose to obtain imagery and do your own rectifications this is particularly relevant.

Since control is the common beginning point for both the RS and the GIS feature class does it make sense to reinvent the wheel on a regular basis? The land survey community in its public form (County Surveyors) and by means of its private practitioners is required to use and sustain the control system. As a GIS professional the survey community is your resource for an accurate grid to establish your base map and support your features for location. The land survey community is a living part of your "expert system" that allows you to access huge amounts of location information and leverage it to your advantage. Some of that information is free in the form of the public record and by all means the GIS user should avail oneself of it. But even more data and insight can be accessed by developing a strong relationship with the land survey community in California.

The absolute advantage of a mature GIS is the capability to depict multiple graphic sources of information in the same plane and hence give a visible and analyzable form to the relationship between those sources. A quintessential problem of all GIS is deciding which feature classes possess the most accurate portrayal of the "truth of the ground" and how that accuracy should be reflected in the final mapping product.

In the current California GIS environment there are many systems, many products and many masters and creators. Theoretically all users will gravitate toward the worldwide model of geographic coordinates and the statewide model state plane coordinates to serve as an anchor for the system. In practice however this has largely not been the case.

To deepen the difficulty, GIS is in many respects now the victim of its own success. The technology and its products are now ubiquitous. Together with the advances in GPS services that have made location finding easy and accurate GIS has seized a huge portion of the governmental, regulatory and developmental environment as its own fiefdom. While this has resulted in a flourishing and vital surge in innovation in these areas it also contains the potential for great peril.

GIS seeks to coalesce a great deal of information from disparate sources to provide an overview that can be achieved in no other way. But what levels of positional accuracy are in place to create the features and to inform all those to whom the feature class would be distributed? Yes, metadata was created to handle this process but metadata is often missing or incomplete. And, yes, the absence or inconclusive nature of metadata should be a warning the user, but is it? Often a GIS layer is the only convenient form of information for a certain concept which can easily be integrated with other elements, so sometimes that feature is used without regard to its limitations. The requirements to perform and deliver often outweigh the caution of professional restraint. Acquiring features by field methods is expensive, office measures can be indefinite, a feature from any source, whatever its caveats, may be all that is available to complete and important task.

Warnings, disclaimers and limitations of use should take care of this problem, but do they really do so in practice? Each day in California a large number of decisions are made based on exhibits and data models that flow from the GIS explosion in the state. These decisions affect the lives, treasure and even safety of California's residents. How can these assets be assured in light of these decisions? Land survey professionals exist as a licensed class of persons whose knowledge of technical measurement and of local land measurement history is a treasure chest for those seeking to develop and maintain a GIS.

As long as GIS was a relatively low-key enterprise creating small and independent projects such problems as arose could be handled directly and with little consequence. But today GIS is wholly involved in the developmental, regulatory and enforcement environments and this has created a pressing need for very high standards of control that can only be solved by integrating the available control initiatives managed by the survey and academic communities of California. The public policy implications of a fully functional GIS cannot be avoided.

If a GIS database is used to detail a local archaeological dig then the large scale ramifications are quite limited. But suppose that the GIS database is used to describe and associate hundreds of digs throughout the state. And then suppose that the results of that depiction and analysis is to craft legislation, let's call it the California Native American Cultural Heritage Preservation Act, and that collection of assets and properties spans hundreds of jurisdictions and thousands of property holders. Yes, it is very likely that each individual unit will be investigated after the fact by traditional field methods. But would it not be vastly more efficient and legislation more appropriately targeted if the initial model was as close to "the truth of the ground" as possible. The integration of a GIS with a highly accurate control frame of reference possesses not only the dimension of efficiency but also that of professionalism and ethics.

GIS will be used. The speed, potential for integration and the possibility of creating convincing, analyzable models assures this. "Everyone is their own cartographer" is a most empowering mantra. Those who are helping to advance this one-of-a- kind technology are doing an immense service to society and virtually all of its members. What can be done to address the error which will inevitably occur in the deeply complex processes of creating and using GIS databases? The traditional model has been to "warn" against inappropriate use. This is manifestly inadequate. The lay user cannot and often apparently will not recognize the essential difference between a "car club" road map and an engineering drawing or a record of survey. The best solution is to return to the source. All practicing users are aware that the future of GIS is not merely software dedicated to analysis and presentation. It is data and the only way out of the difficulties posed by poor data is the way up. Improvement of the quality of the base map is the deep key to all future success.

In cooperation with national governmental and academic interests, the California land surveying community erects, maintains and monitors a complex and increasingly dense system of monumentation and reporting technologies whose sole purpose is to provide a locational master for all dependent purposes within and without the state. Continuously operating reference stations (CORS) and the California High Precision Geodesy Network (HPGN) are merely the backbone of a complex physical and mathematical model that continuously measures and updates geographic locations throughout the state. Part of the responsibility of the land survey community is to recognize and adapt to the changes that GIS and GPS have created in the technical and consumer environments of measurement. Some functions traditionally associated with land surveying are now being and will in the future be conducted by lay persons and experts from other fields such as GIS. This is a reality. But, at the same time, it is the responsibility of others seeking to produce useful work and to establish their professionally credentials to recognize, utilize and nourish the valuable interface between land surveying and the GIS enterprise.

An illustrative example might be a survey field book filed with the materials supporting, describing and delimiting a local control system. This theoretical book has great value of itself but its value is immeasurably increased when it is integrated into a GIS. In that environment it provides a base for feature classes that can be used in conjunction with other elements and the entire system can be used with confidence. From the surveyor's point of view the control may be viewed with all the powers of the GIS harnessed to it. Figures and annotations leap from the mute pages of a book into vigorous life on the CRT and in the database.

In some cases local GIS initiatives historically began with land surveyors, in some cases with IT units and in still others with academics or land use planners and managers. But now the future of GIS and land surveying in California are parallel lines that are rapidly moving toward an intersection somewhere in the discernible future. A possible solution to the inappropriate use of some GIS features is, in part, to establish a method for "branding" all feature models with an easily recognizable system of accuracy statements similar to that used for classing survey monuments. With that completed as a first step all GIS features and processes should begin with inclusion of high level control which can be easily updated and refined as crustal motion and datum change require.

Land surveying and GIS will always possess areas of expertise and business which will not impinge on each other, but at heart they have similar questions to ask. Where is it and what is its relationship to any chosen object or process? Because those questions often take the form what is the context? (GIS) and where exactly is it? (PLS) does not establish a difference in species, merely a difference in overlapping domains and ranges. Integration of purpose, technologies and professional acumen will serve both groups mightily and control is the source from which all things, well, all accurate things, spring. Analysis, visual depiction and rapid digital deployment are the proper concerns of GIS and will be so into the foreseeable future. It makes little sense for those whose involvements are with these concerns to attempt to extend their expertise into areas which already exist and merely wait to be tapped.

In many ways GIS offers the keys to the kingdom to present and potential users. Those who provide the keys will serve themselves and those to whom the keys are offered by leveraging and involving the available resources most directly and with the least redundancy of effort. Art and science combine and sometimes they produce magic. Like Howard Carter's on the threshold of discovery at the tomb of "the Golden Boy" in the Valley of the Kings, we stand ready to enter an amazing, unexplored world. When Carter removed the first the first stone from the inner plastered doorway Lord Carnarvon anxiously said from behind him, "Can you see anything?" Carter was at first mute but then, as his eyes adjusted, said "Yes, I see wonderful things!"

All of those who are involved with GIS and land information have lived to see this technology give birth to truly wonderful things. Before us now lies the great responsibility to see that those wonders are not illusions which mislead or misdirect but instead are solid, repeatable and well-honed manifestations of true description. Then, and then only this technological magic will have inaugurated a true golden age. The technology of GIS is absolutely irresistible; it can perform many functions which could be achieved in no other way. There is a force of expertise in the slick presentation of the material derived from an expert system which is very powerful. To come into its own and to support today's complex decision making environment that material must consistently be spot on. The only way to achieve this is for the fundamental building blocks of control to be tight, current and updateable.

As medieval alchemists discovered, lead cannot be turned into gold. But gold can be melted and recast into "wonderful things" that illuminate the mind and times of the artisan, the governmental mechanism and the public at large. An GIS builder and developer is encouraged to find the gold and those who tend it, mine it, integrate it, be familiar with it and reap all the associated benefits.