Sub-foot Accurate Municipal GIS without GPS

Tempe, Arizona's GIS System

by

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for

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Presentation Goals

- Outline Tempe, Arizona's approach for the past 20 years of developing an accurate municipal GIS landbase without the use of GPS or other GIS-dedicated means of spatial data collection
- Revisit fundamental processes in accurate mapping of landbase data
- Identify value-added results from developing accurate data

GIS Excellence

GIS excellence is not measured in what software you are using, what projection you are working in, how complex you display, label, or attribute objects, how much skill and technology you have in warping something to fit, or that you publish your data to the internet. GIS excellence is the faithfulness you place in transcribing one feature, one point, one line, one boundary to control and authority, then the next one, and the next one, and the next one, etc., etc., etc.

This is the only primary factor as this is the basis for all subsequent actions and activities

GIS Excellence

- Transcription
  - The technical process of taking data from a non-GIS structured format (paper, photos, uncontrolled data, etc.) to a GIS system
- Authority
  - The responsible party or 'owner' of the data being transcribed
- Control
  - The technical 'real world' structure and rules of the environment the data is being transcribed to

General Facts

- CADD-based GIS data systems can store spatial data up to 0.01' and better, and GIS software can manage projections transparently to the technician, analyst, and end user
- Municipal GIS data is primarily built from survey information, even if only scanned or digitized from plats, as-builts, and other documents having information that was surveyed
- GIS spatial data methodology significantly benefits from surveying discipline and principles
- GIS spatial accuracy is *directly influenced* by the conversion and maintenance methodology and *not* by the technology or software

Reality - TGIS (Tempe GIS)

- TGIS spatial data is extremely accurate - in 90% of the areas, cadastral GIS data is 1 in 10,000 accurate to real world locations
- TGIS spatial data is built directly from surveys, plats, and instruments using surveyed bearing and distance - no scanning, digitizing, or other rubber sheeting or warping practices are used
- Less than 1% of TGIS spatial data has been re-surveyed and no GPS equipment or contracts are used to derive accuracy
- The GIS Database Supervisor and Chief Surveyor, and their respective staff, work together to maintain this accuracy
- All spatial anomalies or irregular cadastral issues are reviewed by the GIS Database Supervisor and Chief Surveyor

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Tempe's Mapping issues

(circa 1980)

- Manual maps were out of date, had inconsistent scaling, and duplication of effort between the Engineering Division and Water/Waste Water Division of the Public Works Department
- Current staff could not maintain existing manual maps without significant cost increases and efforts to improve quality
- New technologies at the time were becoming more financially feasible and attainable, and offered more informational capabilities than 'computerized' maps

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The Dream

- Lee Quaas, P.E., City of Tempe City Engineer, envisioned a computerized mapping system for the Public Works Department in the 1970's
- During the 1970's and early 1980's, the Engineering Division evaluated computerized mapping systems
- In the early 1980's the financial costs were deemed to be at a reasonable level and funded by CIP and Water Enterprise funds

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The Plan

- Develop engineering grade computerized maps to support the Engineering and Water/Waste Water issues
- Build quarter section control grid for maps from field measurements done and certified by R.L.S. and create quarter section base maps
- Map landbase information from plats and surveys via COGO techniques
- Map city utility information from as-builts via COGO techniques
- Attribute all map elements for future GIS, LIS, and AM/FM data development

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TMARS TGIS TGIS

- TMARS (Tempe Mapping And Reporting System) conversion project started in 1982 with Rudy Stricklan, R.L.S. retained as content expert
- Quarter section control grid survey completed and R.L.S. certified in 1984
- TMARS project became TGIS program in 1990 with Tempe Computer Mapping staff managing and maintaining GIS dataset
- TGIS program in 1993 expands to multiple city departments (by 2003, up to 320 employees or 20% of the city's employees)

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TMARS TGIS TGIS

- Through all software, hardware, and technology changes since 1985, TGIS continues to use the same production methodology for GIS spatial information management
- No spatial accuracy enhancement project has been performed on TGIS
- TGIS continues to provide accurate spatial information

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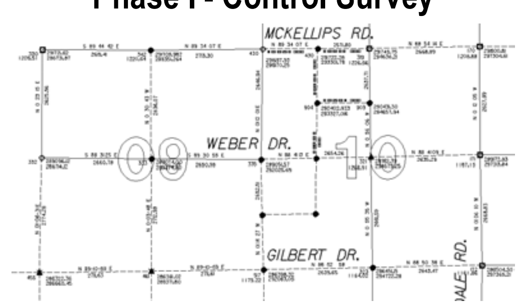
Phase I - Control Survey



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Phase I - Control Survey

- A survey was conducted in the 1st quarter of 1984 to establish the quarter section control network for TMARS
- 200+ quarter corner points in Tempe were recovered to control the survey network
- Survey performed under FGCC Second Order Class II standards
- 10 control points defined and surveyed to FGCC Second Order Class I standards
- All TGIS base maps and related data are defined to this grid

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TGIS / TMARS Projection

- The survey network was established in a custom projection relative to NAD 1927, Arizona Central Zone
- The projection plane is elevated to 1200' above sea level to minimize scale factors of ground-based surveys to TMARS maps
- A false northing and easting is applied to reduce confusion with NAD 1927 values and allow fitting of state level information within the IGDS / MicroStation design plane

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Phase II - Test Section

- A densely populated section was selected to test mapping methodologies
- All mapping done in this section was first done by conventional digitizing practices
- It was determined that digitizing did not provide sufficient accuracy to meet the needs of the Engineering Division
- A COGO (coordinate geometry) approach was used in re-mapping the section and heavily tested for anomalies and errors
- After review, it was decided to continue mapping the entire city by COGO

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Phase III - City-wide mapping

- COGO mapping methodology applied to remaining portions of the city (179 quarter sections)
- City forces and consultant work together in collection and transcription of data
- Consultant trains city forces in COGO mapping methodology and other GIS data management techniques
- Conversion completed in 1989

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TGIS Mapping Methodology

- Conversion *and* Maintenance methodology emulates standard engineering and surveying practices:
  - Establish control grid and define projects to that grid
  - Surveying used in definition of plats, surveys, and as-builts and are defined to control grid
  - Leverage this information with little to no re-interpretation, warping, or other modification

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TGIS Mapping Layout - Part I

- Plat must 'survive' on it own information and is mapped externally to the GIS maps
- Plat is mapped in temporary design file
  - Technician maps outer boundary first, then centerlines, then ROW, then parcels
  - Technician maps all segments by COGO / geometric keyins: MicroStation: `di=345.26,N26^17'22"W`
  - Technician checks closure of all segments as described by the plat
  - Plat is *not* referenced to design file, scanned, tablet digitized or on-screen digitized
- If plat closes within 0.10' it is considered good, otherwise it is returned to Chief Surveyor for review

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TGIS Mapping Layout - Part II

- Temporary map is adjusted to TGIS projection (if needed)
- Map is moved and rotated only to control points and/or basis of bearing called out by plat
- Map is check against adjoining parcels, subdivisions, etc. for proper fit as well as the adjoining boundaries
- Fitting that requires more than an overall 0.25' of adjustment is forwarded to GIS Database Supervisor for review
- Fitting that requires more than an overall 0.50' of adjustment is forwarded to Chief Surveyor for review
- 95% of maps processed require less than 0.10' of adjustment

TGIS Mapping Layout - Part III

- Upon proper fitting of temporary map, map is merged into TGIS map
- Map is attributed with graphical text and tabular information
- Finished map is cleaned by automated cleaning processes and returned to the master source

TGIS Mapping Layout - Part IV

- Utilities, other city-owned infrastructure, and other regions are mapped to cadastral base similar to landbase methodology using information yielded from as-built and other field documents
- All mapped objects must have some legal or other binding description via field check, legal document, or other binding document
- *Mapping system's only authority is to transcribe information as accurately as possible leaving all other authority to responsible organization*

Return on COGO Investment

- Data is used directly for general surveying information and civil engineering plan sheets - little need to create base maps
- Data is synthesized to other GIS platforms (MapInfo, ArcView, Map Guide, etc.) and retains spatial accuracy
- COGO-based mapping provides additional plans checking and possible boundary issues to Chief Surveyor
- Traditional on-screen digitizing on landbase inherits some of the accuracy depending on digitizing method
- Alignment of engineering business practice to GIS methodology provides understand on how the business works

FAQ's - Chief Surveyor

"How does the Chief Surveyor help your GIS?"

- The Chief Surveyor provides the following:
  - Informational assistance in identifying and resolving boundary and spatial accuracy issues
  - Technical support for GIS data procurement issues such as photoimagery
  - Professional support for GIS Database Manager in technical surveying issues and data policies
  - Sounding board for all levels of spatial data management
- Many of these issues can only be handled by an R.L.S.

FAQ's - COGO Overhead

"Doesn't COGO add too much production overhead?"

- COGO approach seems to add 30-40% more production overhead than major forms of digitizing
- Benefits:
  - Accurate spatial locations
  - Better edgematching and fitting of other information datasets
  - Useful returnable information
  - Measurable, reproducible, and correctable results for technicians
  - Better understanding of how things work
  - ***Near zero rework!!!***

FAQ's - NAD 1983 Conversion

"When do you plan to convert to NAD83?"

- Conversion is unlikely nor is needed due to properly defined and managed survey control network and the faithful adherence to the control network
- TGIS data can be written out to any projection as well as use any data from other projections
- Since TGIS projection is equivalent to ground measurements, conversion of production methodology to NAD 1983 would require scaling to NAD 1983 projection surface

FAQ's - Digital plan files

"Why do you redraw plats, etc. when digital files are available?"

- In many occasions, while the text-based information and printed plan is 100% correct, the CADD linework may be inaccurate and not reflect the written bearings and distances
- CADD plans are drawn and printed for 'picture' reasons and not for digital spatial accuracy or GIS importation
- GIS data typically requires special CADD drawing procedures or policies for proper synthesis to GIS datasets which are not adhered to by persons creating plan for printed purposes
- Digital files rarely conform to a usable GIS data structure

FAQ's - CADD-based GIS system

"Why do you use a CADD product than a GIS product?"

- CADD provides more control in drawing and has more available training sources and personnel than GIS software
- GIS software drawing interfaces are not as easy to use than CADD interfaces

Drawbacks:

- More attention in working in CADD is needed than GIS software in object and attribute work
- Interfacing non-CADD GIS data to CADD has translation and adjustment overhead

FAQ's - I want spatial accuracy

"Our spatial accuracy needs work. How do we do what you do?"

- Establish ***real*** section or quarter section survey control - ***This is non-negotiable***
- ***Get away of digitizing, scanning, and rubber-sheeting plans***
- Train staff in COGO and surveying geometry and math
- Map one section of landbase by COGO
- Validate work
- Continue to next section…
- Over the next few sections, validation will not be necessary

Closing Thoughts

- Correct spatial transcription is one of the most important factors in GIS yet least understood and not properly practiced
- If you do the number crunching and mapping right, the work will check out very clean
- If your GIS spatial data is built right, everything will check out very clean
- If you can't do the math or the transcription, learn how
- A GIS Manager who cannot do this needs to learn how
- An R.L.S. is indispensable in these endeavors

Questions & Comments

- Thank you for your attendance and participation -

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