Utility Locating and Mapping

Scoping Subsurface Utility Engineering (SUE) for 3D Design

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Course Objectives: *Project Management Perspective*

- SUE Quality Level (QL) review from the FDOT Plans Preparation Manual
- Simplistic overview of methods and some of the main tools to achieve QL's
- Strengths & Limitations of the locating tools.
  - Equipment, Environment, & Experience
- The 3D paradigm
  - Challenges in depicting utilities for the designer
  - Combining intermittent Utility Locations vs. Continuous Imaging in the x, y, and z perspective
- Cost vs. Risk- a.k.a- obtaining the necessary "Value Proposition" while maintaining a "Standard of Care".
- Where do we go from here? What are the needs? What is Best Practice with the needed change in approach?

Toolbox of technology and knowledge combined

- Think about your own resume'
  - ✓ What are your knowledge's, skills, and abilities?
  - ✓ What would you consider your expertise's to be?
  - ✓ Are you an executive, manager, supervisor, project manager or technician?
  - ❑ Your level of knowledge and responsibilities about a particular technology or science usually reflects your "need to know" at solving a particular problem or delivering a certain product.
  - ❑ From a Project Management Perspective one of your most important responsibilities is managing RISK.
  - ❑ Risk is tied to cost. How do you interpret and manage this?
  - ❑ When it comes to underground utilities your primary focus to solve this issue should be in the best interest of the end user of the data and information. This is a huge responsibility because of the financial impacts and the amount of stakeholders involved.

What is Subsurface Utility Engineering (SUE) ?

- ❑ **A proven engineering approach. (30 years)**
  - ✓ **Consists of processes, technologies, professional experience and judgment.**
  - ✓ **Research, locate, survey, and then depict, with varying degrees of accuracy underground utilities. You can then *properly manage* and perform confident risk analysis with underground utility impacts.**
  - ✓ **This enables the user and owner to assign & mitigate risk by having knowledge of the accuracy of the utility information.**
- ❑ **Engineers and owners are therefore empowered by having reliable data to make sound design and business decisions.**

*In SUE there is an eclectic mix of **expertise.** You can not reliably map what's below the surface without the proper tools and expertise.*

- Surveyors
- Engineers
- Utility Engineers
- Utility Construction
- Geologists
- Geophysics
- Vacuum Excavation Expertise (Heavy trucks, cyclone vacuum technology, construction methods.
- Experience with the distribution methods and science behind Electric, Telephone, Gas, Water, Sewer, etc. systems
- Materials, Scientific properties
- History-how things were constructed through the years perhaps in excess of 50 years ago
- Hopefully……the guy that was there when it was installed or perhaps he dug it up or hit it once ☺
- Very difficult to be an expert in all these areas, but you can provide yourself with knowledge to help you manage the risks and costs.

FDOT Plans Preparation Manual 2013 (PPM) Chapter 5.3

5.3 Utility Locates

It is the responsibility of the designer, with the assistance of the District Utility Office to determine the locations and Quality Levels necessary to obtain the needed utility information. The description of the information obtained from each Quality Level of locate is provided in ***Section 5.3.1***.

It is the responsibility of the UAOs to provide Quality Level "D", "C" and "B" locates on request. In some instances the UAOs can provide Quality Level "A" locate information.

Quality Level "A" locate information is to be obtained when proposed construction operations are suspected to be within three feet (3') of major utilities. Major utilities are those underground and aboveground utilities that if damaged or required to relocate would cause high construction costs to the UAO, other utilities, or FDOT. The UAO may be able to provide this information; however, it is the responsibility of the Designer to obtain this level of information when needed and when the UAO will not be providing this information. The decision to proceed to construction without this information shall be made with consultation with the District Utility Office, appropriate construction personnel and the UAO.

SUE Quality Levels: Chapter 5.3.1

5.3.1 Quality Levels for Utility Locates

The following identifies the key elements within the quality level of utility locates in ascending order about which Subsurface Utility Engineering is applied:

Quality Level "D" - Existing Records
Quality Level "C" - Surface Visible Feature Survey
Quality Level "B" - Designating
Quality Level "A" - Locating

- Although QL's "D" and "C" are considered SUE it is not until you get information in QL's "B" and "A" that you in most cases begin to achieve a **standard of care** for design and construction activities.

- Always think of the end user, this is probably not you.

So the question is, where are you saving or spending the money? As the designer your job is to mitigate the risk.

Quality Level "D"

Quality Level "D" locates are information obtained solely from a review of utility records for facilities that may be affected by the project. The comprehensiveness and accuracy of such information is highly limited. Even when existing information for a utility in a particular area is accurate, there are often other underground systems that are not shown on any records.

Quality Level "D" may be appropriate for use early in the development of a project to determine the presence of utilities. Applicable records may include previous construction plans in the area, conduit maps, direct-buried cable records, distribution maps, transmission maps, service record cards, "as-builts" and record drawings, field notes, county, city, UAO or other geographic information system databases, circuit diagrams, or oral histories. The records should be reviewed for indications of additional available records, duplicate information, and credibility of such duplicate information, and need for clarification by UAO's. The end product of a Quality Level "D" would be a utility composite drawing or equivalent. The engineer should also make professional judgments regarding the validity and location of topographic features on records versus current topographic features (when available) and conflicting reference of utilities. The engineer should indicate the quality levels, utility type and/or ownership, date of depiction, accuracy of depicted appurtenances, end points of any utility data, active, placed out of service, size, condition, number of jointly buried cables, and encasement.

Quality Level "C"- *Topographic or Location Surveys*

Quality Level "C" locates are information obtained to augment Quality Level "D" information. This involves topographic surveying of visible, above ground utility features such as poles, hydrants, valve boxes, circuit breakers, etc. If previously surveyed, check survey accuracy and completeness for applicability with the existing project. Correlate applicable utility records to the surveyed features, taking into account the geometries and indications on the records of these surface features. Determine when records and features do not agree and resolve discrepancies. Additional resolution may result from consultation with UAOs. Quality Level "C" may be appropriately used early in the development of a project and will provide better data than Quality Level "D" information alone. Designers cannot be sure their design is appropriate nor can construction proceed without caution when using information for underground utilities based only on Quality Level "D" and "C" locates.

Quality Level "B"- *Designating, Geophysical Prospecting, Locates*

Quality Level "B" locates are information obtained to augment Quality Level "C" information. Quality Level "B" locates are information obtained through the use of designating technologies (e.g., geophysical prospecting technologies). This is an application using scanning technologies, most of which have very specific capabilities and limitations that vary with site conditions. Applying a variety of techniques is essential to the process of preparing a comprehensive horizontal map of utilities and other underground structures on the site. Designating technologies are capable of providing reasonable horizontal information but provide limited vertical information. Mark the indications of utilities on the ground surface for subsequent survey. Care should be taken to differentiate markings placed on the ground for design purposes from those placed on the ground for damage prevention purposes. Survey all markings that indicate the presence of a subsurface utility. This survey should be to the accuracy and precision dictated by the project's survey control. Depict all designated utilities. Correlate the designated utilities' depictions with utility records and/or surveyed appurtenances to identify utilities that may exist but were not able to be designated. Resolve differences between designated utilities and surveyed appurtenances. Recommend to the project owner additional measures to resolve differences if they still exist.

Quality Level "A"- *Test Holes, Pot Holes, VVH's, Locating*

Quality Level "A" locates provide the highest level of accuracy of utility locations in three dimensions. This Quality Level may apply manual, mechanical, or nondestructive (e.g., vacuum excavation) methods to physically expose utilities for measurement and data recording. Quality Levels "B", "C", and "D" locates are incorporated in Quality Level "A" locates. The designer should obtain Quality Level "A" locates at highway/utility conflict points where verified information is necessary. Select an appropriate method of gathering data that will achieve the accuracies and precision required by the project. These accuracies are currently typically set to one half (0.5) inch vertical and to applicable horizontal survey and mapping accuracy as defined by the project owner. Excavate test holes exposing the utility to be measured in such a manner that protects the integrity of the utility to be measured. Comply with applicable utility damage prevention laws, permits, and specifications and coordinate with Utility and other inspectors, as required. Determine (a) the horizontal and vertical location of the top and/or bottom of the utility referenced to the project survey datum; (b) the elevation of the existing grade over the utility at a test hole referenced to the project survey datum; (c) the outside diameter of the utility and configuration of non-encased, multi-conduit systems; (d) the utility structure material composition, when reasonably ascertainable; (e) the benchmarks and/or project survey data used to determine elevations; (f) the paving thickness and type, where applicable; (g) the general soil type and site conditions; and (h) such other pertinent information as is reasonably ascertainable from each test hole site. Resolve differences between depicted Quality Level "A" data and other quality levels.

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http://www.google.com/search?q=electromagnetic+locating+images

Designating Equipment-
QL "B"

Receivers

Transmitters

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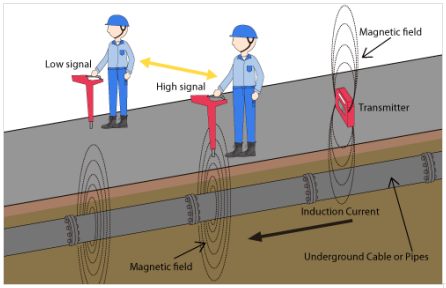
Designating- QL "B"

EMC & EMI Methods



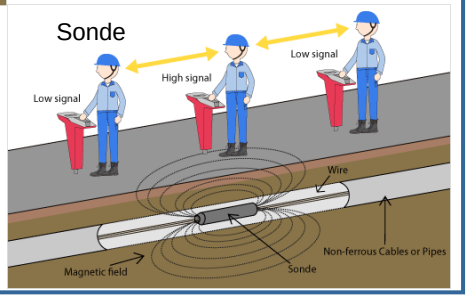
Direct Connect

Locates an electro-magnetic field resulting from an electric current flowing on a line.

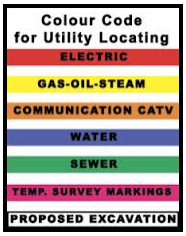
✓Conductive (EMC) or Inductive (EMI) Methods.

Induction Clamp

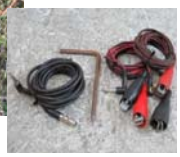
Sonde



Designating – QL "B" - *EMC & EMI Methods*



Mark and Survey



Designating- QL "B"-Ground Penetrating Radar (GPR)

RADAR is an acronym coined in 1934 for:

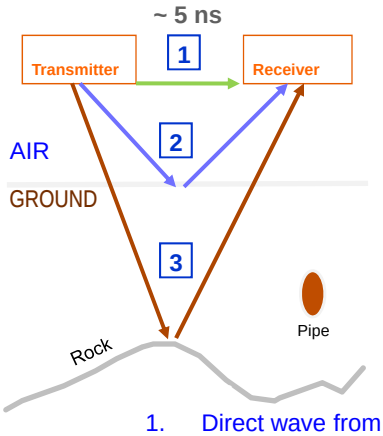
RAdio **D**etection **A**nd **R**anging

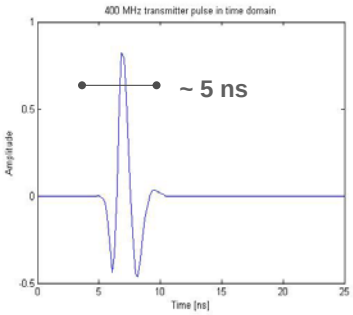
- Origins of its use was for tracking of aircraft or surface features of a planet.

Typical 1 or 2 channel GPR

- GPR operates by using **Radio Frequency Pulses** and measuring in Time **Domain**……the time it takes the signal to travel from a transmitter and return to a receiver from reflecting off of an object. In all cases time = distance, in our case……depth.
- Frequency ranges are typically 200mhz to 1000mhz in commercial GPR.
- Frequency selection is critical to depth (limits) and resolution (detail)

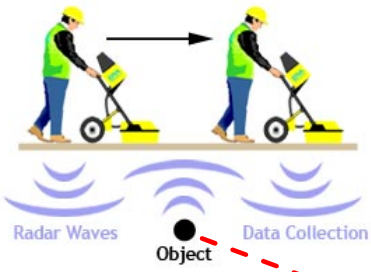
Transmitter Pulse and Wave Paths



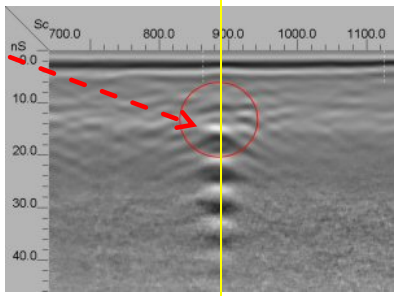


1. Direct wave from transmitter to receiver through air
2. Reflection of ground surface through air
3. Reflection of subsurface target, mainly through ground

GPR- as it moves along……



Mark the utility in real time with paint….



….and/or store object into data collector

http://www.google.com/search?hl=en&site=imghp&tbm=isch&source=hp&biw=1920&bih=976&q=ground+penetrating+radar

Radar Tomography- (RT)- QL "B+"

- Highly advanced technology and process combining GPR, Survey tracking, and computer image processing software to provide an accurate continuous three-dimensional image of structures, objects, utilities, cracks, voids, trench lines, or other differentiating subsurface features.
- This continuous coverage of imagery geo-locates any geophysical anomaly in the subsurface within the area of GPR limitations. The material the objects are made of is not generally an issue.
- "Tomography" is a common term that refers to any imaging by sections or sectioning through the use of wave energy. Most of us are familiar with MRI's, Cat Scans, etc. used in the medical field. This imaging does not yet occur in real time. The data and positional information are stored and the product is created in post processing.

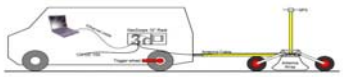
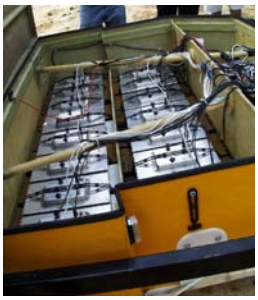


Figure 8 - Typical GPR setup with 4-wheel trailer.

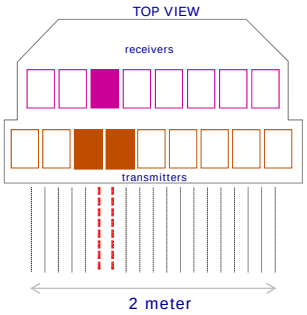
Figure 9 – GPR antenna mounted on the front of a survey vehicle.

Different Arrays and Delivery Systems

Mala Geosciences GPR Array



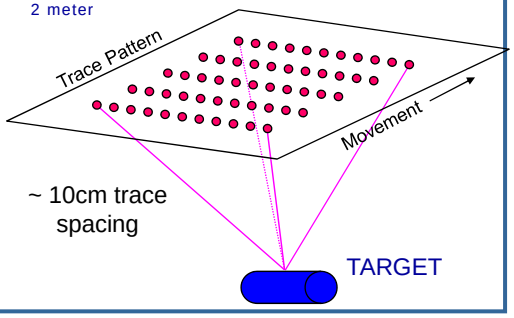
200 MHz array



- 200 or 400 MHz

(Frequency dictates depth vs. resolution)

- 17 GPR antennae (9 Tx/8 Rx)
- 16 channels
- Control Box
- Trigger Wheel
- Laptop (on board vehicle)



~ 10cm trace spacing

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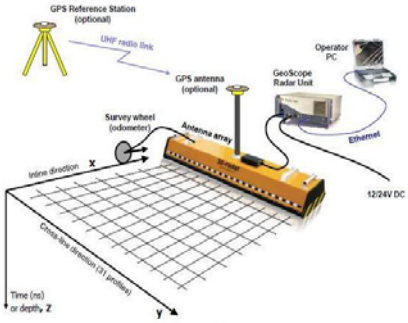
3D-Radar Step Frequency Array

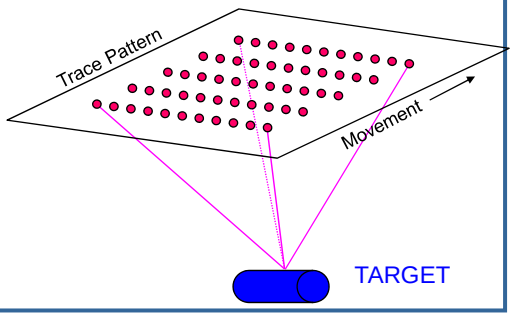


GeoScope GPR system overview.

- 150 MHz thru 1.8 GHz MHz

(Frequency dictates depth vs. resolution)

- 62 GPR antennae (31 Tx and 31Rx)
- 1 thru 31 channels
- GeoScope Control Unit
- Trigger Wheel
- Laptop (on board vehicle)



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Position Tracking

Radar Array is tracked via robotic laser or GPS at all times. Position data is recorded and referenced to survey control point's based on reproducible project datum's

Robotic Total Station
*(**OR** Survey-grade GPS)*

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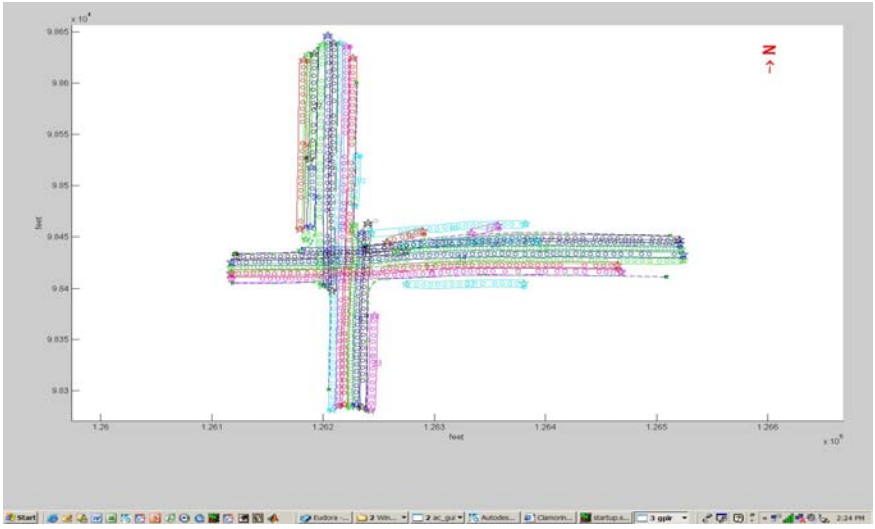
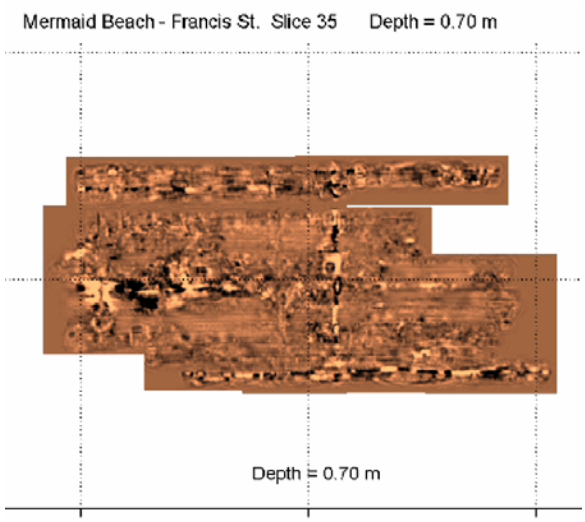
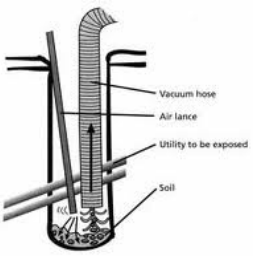
RT Survey Acquisition or Data Collection

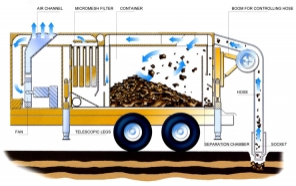


RT Imagery- QL "B+"



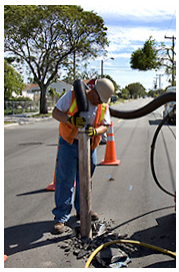
Test Holes- QL-"A"- *Vacuum Excavation*





Excavation either by high pressure air or water. The spoil is removed by a cyclone vacuum system.

Properly done this is non-destructive and minimally invasive.



http://www.google.com/search?q=test+holes

Test Holes- QL-"A"- Vacuum Excavation

http://www.google.com/search?q=test+holes

Advantages and Limitations- Electromagnetic

Advantages:

- Can be Fast
- Not labor intensive
- Affordable
- Ample companies and competition
- Accurate horizontally to generally 18 inches from where the strongest signal in achieved (manufactures disclaimer under best of conditions)
- Vertically it will give you a depth but it generally known to be 20-30% of the actual and this is with an experienced locator.

Advantages and Limitations- Electromagnetic

Limitations:

- Lack of proper Locator experience and skill level.
- Will not locate plastic pipes without a trace wire.
- Underground Congestion-"Signal Jump"
- Is a great damage prevention tool but…..

Knowledge, Experience and Environment

- Proper Frequency Selection & Modulation
- Induction and Connection Access and breaks in conductivity.
- Limited Connection Points
- Sheathing and Coatings

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Advantages and Limitations- Electromagnetic

Overhead Utilities

Distortion and Inconsistent results

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Advantages and Limitations- Electromagnetic

Adjacent metal objects

Can draw or steal the signal and impact horizontal accuracy

Larger and closer than what you are trying to locate

Advantages and Limitations- GPR

- Advantages:
  - ✓ Improved horizontal and vertical accuracy over designating by other means.
  - ✓ Ease of equipment use.
  - ✓ Locates non-conductive (plastic, clay) pipes.
  - ✓ Not impacted by adjacent utilities.
  - ✓ Can locate the edges of vaults, manholes, and concrete, foundations, pavement thickness, sub base, etc.
  - ✓ A good complementary tool to EMI/EMC

Advantages and Limitations- GPR

- Limitations
  - ✓ Conductive Soils-Clay
  - ✓ Brick Pavers-Clay
  - ✓ Ground Water-in particular salt
  - ✓ Attenuation or noise in the data
  - ✓ Polarization-horizontal movement for optimum results
  - ✓ Can not tell what the object necessarily is. Reflects from anything in the soils of different density.
  - ✓ Operator experience in locating utilities. (Understanding the utility landscape)
  - ✓ Normally only practical in a “real time” solution (paint on the ground)
  - ✓ Generally….a slower process than EMI/EMC
  - ✓ Burdensome if this is the only weapon you show up with on a congested site.

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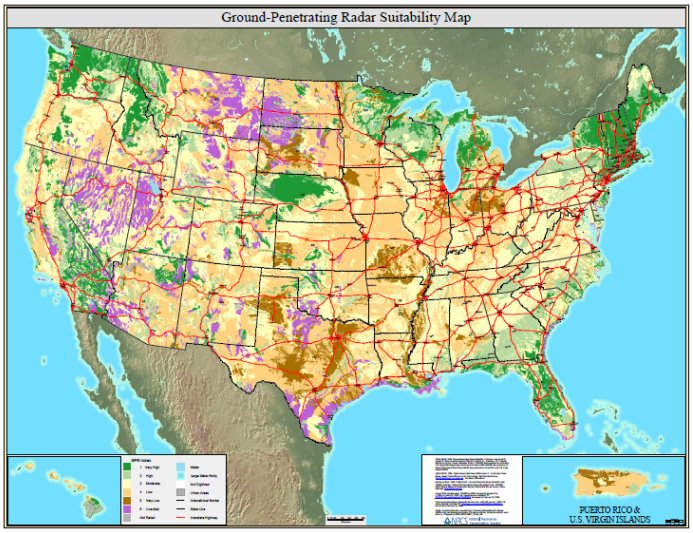
Advantages and Limitations- GPR



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Advantages and Limitations- *Radar Tomography*

- Advantages
  - ✓ Collects and stores continuous data
  - ✓ Experience of the operator is not as critical to resolve geophysical interpretation of objects. Just collect the data for the expert technician.
  - ✓ Creates linear features or shapes in post processing
  - ✓ Fast and indiscriminant compared to other methods
  - ✓ Very little need to address utility types and surface features to collect data in the field with this tool.
  - ✓ A true 3D tool.
  - ✓ Gain some knowledge of the size of the pipe.
  - ✓ Can see many other objects out side of utilities that impact construction costs Trolley tracks, abandoned utilities, concrete, etc, More accurate estimates.
  - ✓ Because you get an accurate image, you know where to dig and about how deep to excavate for further verification of information
  - ✓ Can eliminate a high percentage of test holes.
  - ✓ Tells you where stuff “isn't”

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Advantages and Limitations- *Radar Tomography*

- Limitations
  - ✓ Conductive Soils-Clay
  - ✓ Brick-Clay
  - ✓ Ground Water-in particular salt
  - ✓ Attenuation or noise in the data
  - ✓ Polarization-horizontal movement for optimum results
  - ✓ Can not tell what the object necessarily is but can resolve this in post processing.
  - ✓ Not real time. (Not really an issue for design)
  - ✓ “Sweet spot” for signal frequency. Shallow detail for maximizing depth.
  - ✓ Not really good a resolving a less 1” line or smaller at any depth.
  - ✓ Needs some verification of depth as part of the process to solve for the dielectric (wave speed) to achieve to best depth solution (0.5 ft.). More when the soil properties change with frequent rain in porous soils
  - ✓ Large footprint for the array and vehicle.
  - ✓ MOT required, is disruptive to traffic but this work can be done at night.
  - ✓ Is more expensive but you get much more information and it will eliminate the amount Test Holes. So there is a trade off. It is a worthwhile investment in the urban environment.

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Advantages and Limitations- *Test Holes*

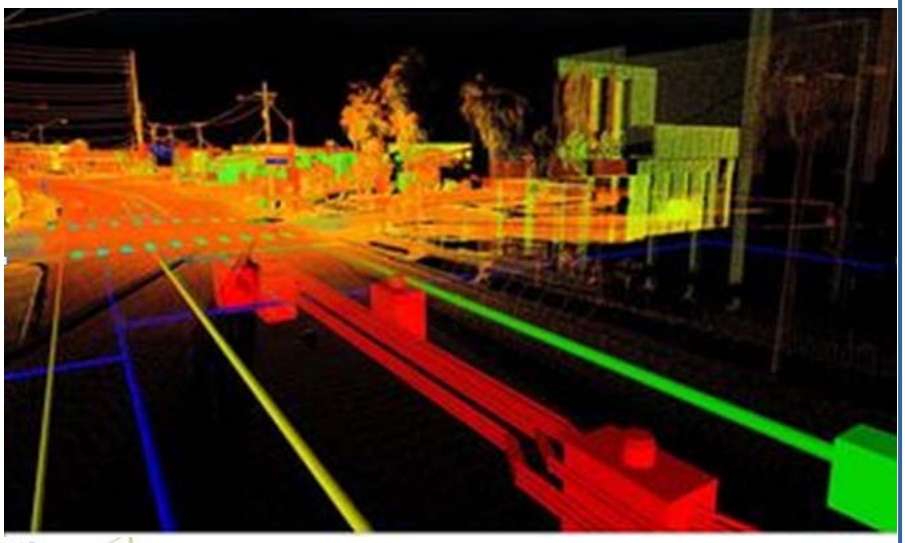
- Advantages:
  - ✓ Well… you just dug it up.
- Limitations:
  - ✓ Well… you just dug it up. Now you need to fill it in and restore it.
  - ✓ MOT intensive.
  - ✓ Noise Issues in some jurisdictions
  - ✓ Access-Large footprint.
  - ✓ Expensive and really expensive to Swiss Cheese an area.
  - ✓ Depth-wet, or difficult soils. Rock, large debris.
  - ✓ If you use water…..you need dry or special backfill.
  - ✓ Pavement restoration.

3D Design SUE products…3D Paradigm

- With all of the various accuracies, methods, and results that can vary because of environmental conditions and provider skill…….how do we understand this information if it is shown in the 3D perspective?
- How do we get there from here and how do we "best serve the end user"?
- Who is the end user? With GIS it may and should extend beyond construction.
- Who will own the issues and problems if there is not clarity and understanding of the information?

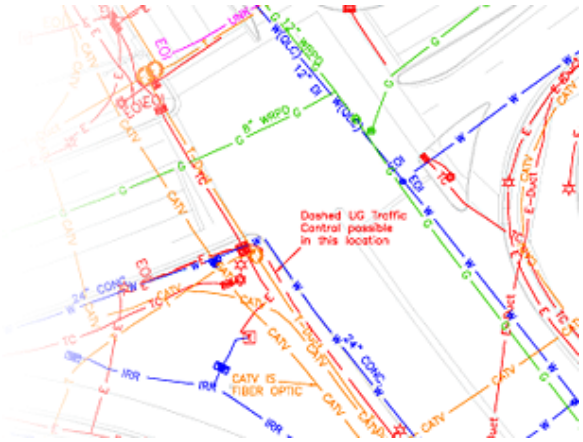
Pretty…..but is it accurate enough for design?

Underground Imaging?



How do we best communicate the accuracy of the existing underground utilities in 3D plans?

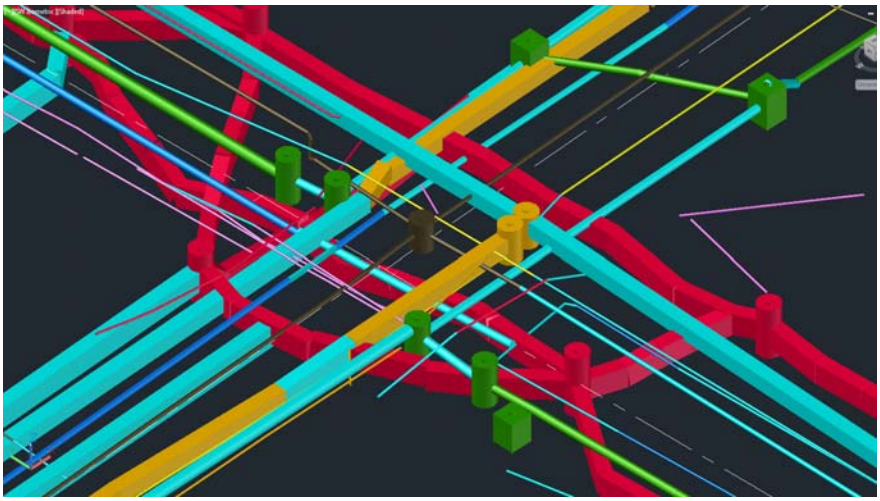
- There is a danger of building false confidence if the user does not understand the QL's.
- Visualizing the underground environment can be a very powerful tool for the designer but they must be aware and always consider the accuracy of the depicted utility individually or even in sections of the same utility.
- This really is not much different than now but our goal in 3D Design is to create a better, more accurate product for the contactor.

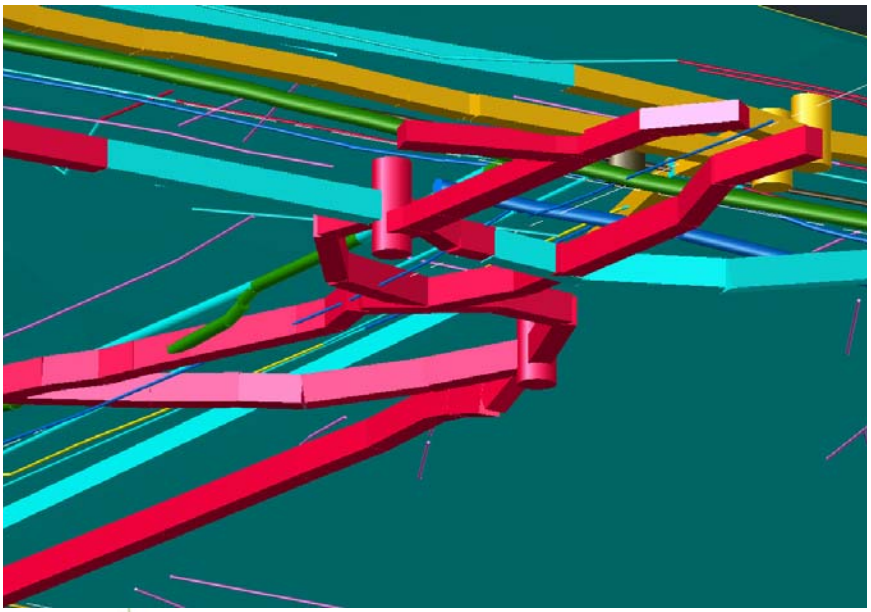


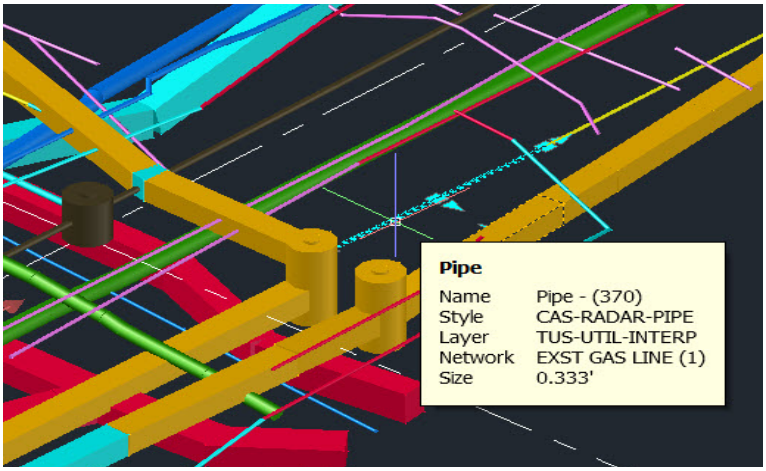
The 2D SUE world

We have made great progress in the last 20+ years……but it has and continues to be a struggle to educate the vast amount of engineers in this country.

We are going 3D with these existing locating technologies…..count on it.







The solution may sound and be simple. The training will need to be exhaustive and consistent.

In conclusion:

- There are many stakeholders with allot at stake. As partners, we need to develop strict standards of practice and be consistent, predictable, and repeatable (CPR).
- Best Practices statewide will benefit the tax payer, private enterprise, and Florida will be looked at as a leader in this area.

Questions:

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