White Paper

Subsurface Investigation Methodology, (SIM)

"The right people paired with the right technologies"

Introduction:

According to the Common Ground Alliance (CGA), over the last 20 years improperly located or not located subsurface utilities have caused $1.7 billion in damages and resulted in 1,906 injuries with 421 fatalities.

The CGA represents a body of industry stakeholders that advocate for the 811/One Call utility funded public property locating service. Part of this advocacy is publishing the "Dirt Report", an awareness document of the previous year's utility strikes nationwide. Their efforts to mandate the use of the 811/One Call system has resulted in legislation across the US that requires calling the service before excavation.

Most—if not all—of these losses could have been avoided through a detailed site investigation using multiple technologies and highly trained personnel.

Outside of the free 811/One Call public property utility location service, there is a vibrant private property utility location market. Contractors that service this marketplace use specialized technologies like ground penetrating radar to image and mark-out underground utilities, as well as scan concrete for critical targets like structural steel embedments. These two locating services are widely used in the construction industry to increase site safety and limit damages to unknown utilities and structural elements.

The largest contractor in the private utility location market is GPRS. In 2017, GPRS completed over 40,000 projects with an error rate of less than ½ of one percent. This success can be attributed to the experience-driven training and technologies used on sites across the US.

GPRS subscribes to a comprehensive approach to conducting a subsurface investigation. This approach is referred to as Subsurface Investigation Methodology or *SIM*.

Purpose:

The purpose of this paper is to quantify the components that form the *SIM* process. Universal adoption of the methods and applied technology strategies used during the typical subsurface investigation will yield higher quality results for the end client and lower hit rates for the contractor. The scope of this paper is limited to the private property underground utility location market and the location of critical embedments in concrete.

Subsurface Investigation Methodology, (*SIM*):

SIM, Subsurface Investigation Methodology is a guide to using the locating technologies of an electromagnetic receiver and ground penetrating radar combined with a proven training approach to achieve a very low investigation error rate.

SIM contains two primary elements, the human asset and the technology asset. The best site results are accomplished when the experienced, trained field technician can utilize multiple technologies in a comparative analysis of data. Thus, a highly skilled technician can locate the same target using multiple technologies resulting in confirmation of findings and results.

SIM is detailed in the following sections:

1. Human Asset, Experience-Based Training
2. Technology Asset, Multiple Technologies
3. Applied Methods and Practices

SIM, Human Asset

Prequalification: The analytical thought processes of the field technician is an important part of *SIM*. Field technician applicants prove problem-solving skills through rigorous interviewing and testing. The testing details the candidates' ability to understand various puzzle pieces and how they fit together. The test simulates many of the challenges they will face in the field.

Experience-based training: This element of *SIM* greatly exceeds the industry standard by requiring a minimum of 8 weeks of field practice and mentorship.

The ASNT document 'Recommended Practice SNT-TC-1A (2011)' recommends 8 hours as a minimum for training and 60 hours practicing GPR in order to be a certified NDT Level I in Ground Penetrating Radar.

SIM requires 80 hours of classroom/hands-on training and 320 hours of mentorship in the field.

Pre-classroom field mentoring: The *SIM* process requires an in the field mentorship of the employee prior to classroom training. This upfront investment in time has benefits for the employee as well as the employer. This training is a four-week process with the following benefits:

- The employee is exposed to the tools and the field practices, thus confirming their choice to pursue the trade of locating utilities and scanning concrete.
    - This mentoring period affords the employee the ability to place themselves in the role in the market they ultimately will service.
    - The employee is also exposed to the working culture, responsibilities, and expectations. Each new field person will work with several mentors.
- The employer can expect:
    - An employee that will have real-world application knowledge of the technologies they will be taught in the classroom. Thus, classroom work will be more effective.
    - An employee that has already created social bonds with a peer group in their region.

Classroom Training: This part of *SIM* fully immerses the field tech into the established standard operating procedures (SOP) applied to both concrete scanning and underground utility locating. The training also includes background theory for the technologies applied in the field. A critical component is the understanding of where the technologies will work well and where they will not. This training is two 40-hour weeks.

Topics of training:

- Maximizing equipment applications
- GPR theory
- EM theory and application
- GPS point mapping
- Site safety JHA forms
- Site communication, pre-scan and post-scan
- Target mark out
- Construction knowledge of all types of concrete slabs
- Post tensioning structural layouts
- GPR data interpretation for concrete slabs
- GPR data interpretation for subsurface applications
- Underground utility and UST locating procedures

Post-classroom field mentoring: Returning to the field after getting an understanding of the theory opens new doors for the field technician. Understanding why and how the data they collect is being impacted by subsurface interferences allows for better adjustments to the equipment. Each new field employee will remain in the mentoring phase of training until their confidence has been built. Their release into the field as an independent field tech only takes place upon approval from the Area Manager. This mentorship is a four-week period.

This investment of time and money into the field technician plays a critical role in the success of *SIM*. Shortening this process opens the field technician up to potentially making mistakes. Much of each field technicians' success relies on their own confidence level with the equipment and the data that is collected. If training is inadequate, the technician will struggle in the role.

Quality Checks: In addition to ongoing safety training as well as technical training, the field technician will be subject to quality checks on their work. As an example, the Area Manager for GPRS is responsible for quality-checking field personnel per the SOP that has been taught through mentoring and in the classroom.

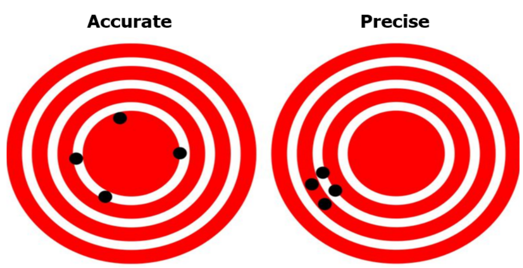
SIM, Multiple Technologies Asset

SIM requires multiple technologies to be used in an investigation. This multiple technology strategy provides for redundancy in findings, thus increasing the precision of the investigation. The primary two technologies for *SIM* are the traditional pipe locator/electromagnetic receiver and ground penetrating radar, (GPR).

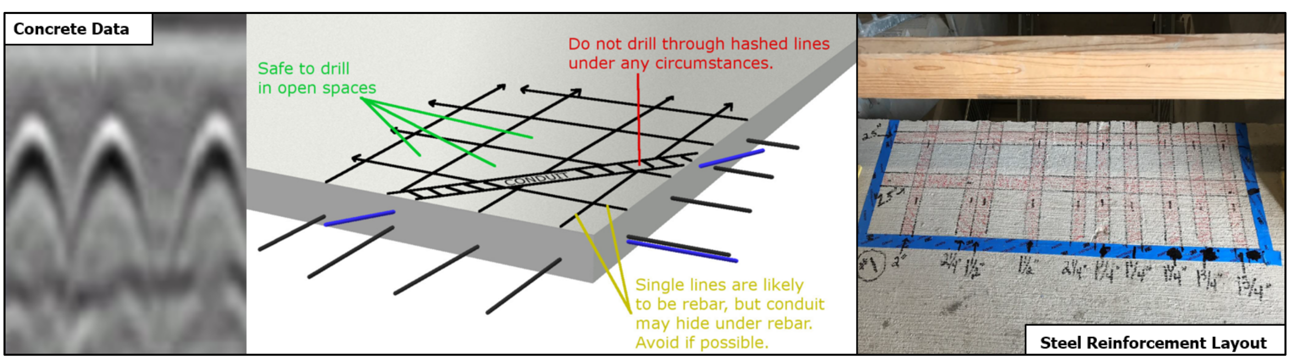
As with any investigation, more data points will bear out the best results. Results that are as close as possible to accurate and precise will yield the best outcome. In the case of locating underground utilities in a non-destructive way, accuracy and precision can be understood as the following:

Accuracy can be defined as the proximity that can be achieved to a known value. This is difficult when working with the potential of unknown values. Accuracy can be confirmed by exposing the located target and therefore comparing results to what is true. This is not typically done due to the general acceptance of the technologies used as being relatively accurate for practical excavation purposes.

Precision can be defined as detecting the same target in the same location multiple times. Precision is increased when more than one investigative technology is applied. This high level of precision in a *SIM* investigation is possible due to the use of GPR and an electromagnetic receiver. However, if one of the technologies suffers inconclusive results based on site interference or an unfavorable soil type, one technology may need to be accepted as the only reliable results.



This discussion of accuracy and precision is different for scanning concrete for critical targets like embedded PVC conduits. The primary technology used is GPR. Accuracy and precision are a function of calibrating the equipment to the known wave speeds in concrete. Thus, a layout of targets on the surface of the slab will be accurate conservatively within ¼" to the right or left of the center mark of the target identified. Depth can be as accurate as +- ¼". Precision is achieved through several scans taken of the same target in different directions.



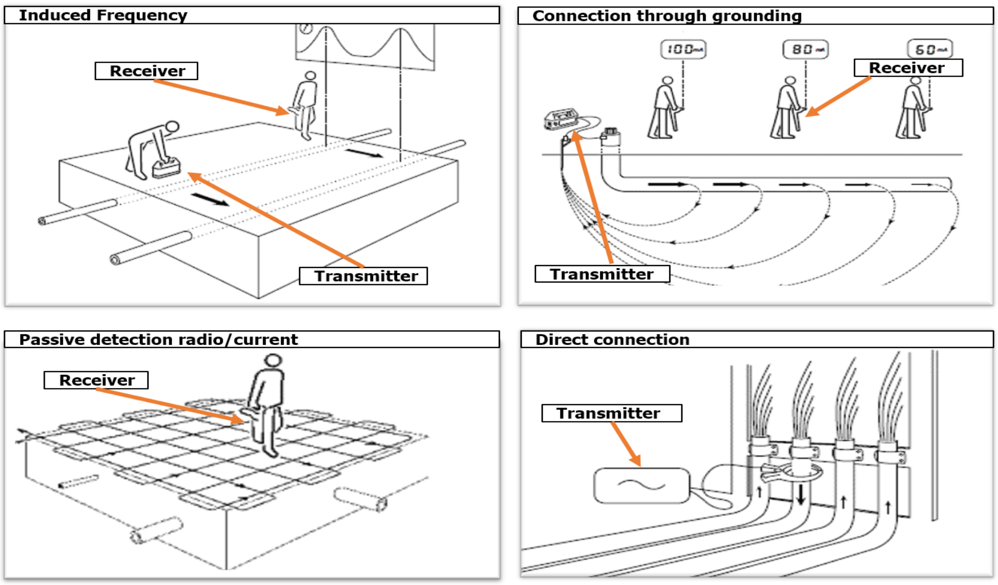
Additional to GPR being used to image steel reinforcement in the slab, *SIM* also calls for a passive sweep of the pipe locator/EM receiver to confirm the area has no energized conduits. GPR is capable of imaging a plastic pipe in concrete but cannot determine if the conduit is energized.

Understanding the two primary technologies of *SIM* is a requirement of the field technician. Operating principles and the basic technology theory are key to maximizing scan data on site.

***SIM*, Multiple Technologies Asset**

Technology 1: The traditional pipe and cable locator is used to detect electromagnetic fields associated with electric current flow on a buried pipe or cable. The equipment is comprised of a receiver and transmitter. The receiver will register electromagnetic fields and frequencies passively or that have been induced or conducted.

This equipment has several ways of being applied to the *SIM* investigation:

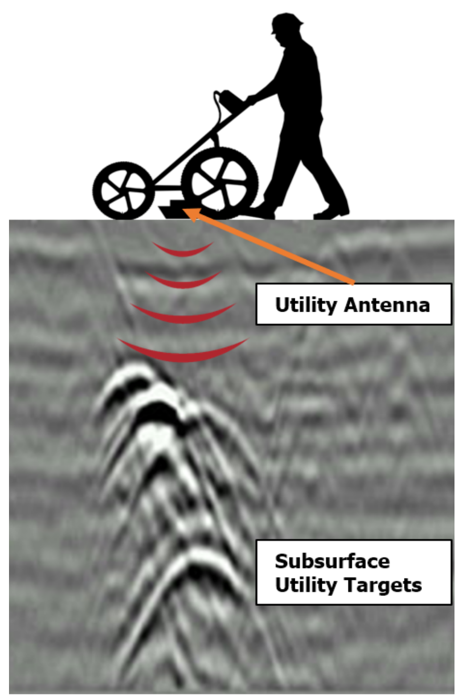


Technology 2: Ground Penetrating Radar (GPR) uses an electromagnetic pulse directed into a subsurface material by an antenna. This pulse propagates through the material at a particular speed determined by the atomic structure of the material.

When the pulse encounters a different material or subsurface target, there is a speed change thus a reflection back to the antenna is created as the pulse continues to move away from its source with less energy. The reflective energy is then received by the antenna, digitized, and imaged on the system controller screen.

The image displays the reflection or subsurface target in almost real time. Depth of target, amplitude/brightness of reflection, and relative size of target are detailed in the image.

Data collection: Data is collected by moving the antenna and control unit over the area of suspected subsurface targets. As the antenna is passed over the ground or concrete, the image builds on the controller screen. When a target is realized, it is marked by the field technician with paint or flags.



SIM, Multiple Technologies Asset

Technology 1 Expectations: The traditional electromagnetic (EM) locator will only yield good results based on the technician's ability to apply it to the site. The four modes of operation detailed below will locate, identify, and trace various underground utilities. The application of SIM on site is to exploit more than one of the four methods, thus assuring a high level of accuracy and precision.

Direct Connection: A direct connection to the underground utility is normally the first option due to its high level of accuracy. This method sends an electrical current through a conductive utility or tracer wire, thereby creating an electromagnetic field that can be detected by the receiver. This method can only be used if there is access to the conductive surface of the utility in question.

Induction: Induction can be used when there is no access to a conductive surface of the utility. An induction clamp can be placed around a utility or the transmitter can be used to emit a field at a high enough frequency to induce a current onto conductors in the area. The induction clamp works best when the conductor is grounded at each end. Inducing directly with the transmitter can work very well for a utility for which there is no access but the generated field will also induce other conductors in the area so it can be difficult to isolate an individual utility.

Passive Operation: Passive Operation is normally the final option but should always be performed. A passive sweep can be used to confirm markings from other methods but will also indicate unknown utilities that are emitting an electromagnetic field. This method is limited to detecting conductors around which there is already an electromagnetic field being created. It will detect either 60 Hz frequencies created by electrical current, cathodic protection frequencies, or various radio wave frequencies being carried by conductors within the utility. The type of utility can only be determined by tracing the utility to a surface feature or a logical end point.

Sonde/Rodder Method: Temporary Insertion of a sonde and/or traceable rodder can be used to trace nonmetallic utilities such as sewer and storm drain lines. A sonde is a battery-powered transmitter that can be pushed through a pipe in order to pinpoint specific locations along the pipe with a high-powered signal. A traceable rodder allows the technician to send a conductor through a nonconductive utility, send current through the rodder, and thereby trace the nonmetallic utility for the entire length of the rodder. This method requires access to the inside of the pipe and care must be used to ensure that the pipe is a sewer or drain line as opposed to an empty conduit which could potentially lead back to a live electrical circuit.

EM Depth Expectations: Utilities can often be located at depths of up to 20' or more depending on a variety of factors. Accuracy Expectations: the equipment has the ability to pinpoint a utility with a very high level of accuracy but this accuracy depends on the ability of the technician to use the equipment properly and to recognize when there will be problems with accuracy such as distortion in an electromagnetic field.

Technology 2 Expectations, Ground Penetrating radar, (GPR):
GPR has many advantages; it can detect both metallic and non-metallic objects in the ground and in concrete. It also can image previously disturbed soils, thus detecting excavations if the soil types are different enough to cause a wave speed change.

GPR depth penetration in soils for utility locating can range from approximately 2 feet to 12 feet. Performance is reliant on soil conditions and the frequency of the antenna. Higher frequency antennas will achieve less depth penetration but with higher resolution and lower frequency antennas will achieve more depth penetration but with lower resolution. The same rule applies to concrete. Typical depth penetration in concrete is 18 inches and sometimes more.

Heavy clay soils attenuate the GPR energy rapidly and create a barrier for the radar signal. Penetration depth can be less than a few feet whereas penetration in sandy soils can be much greater. GPR's ability to image an object depends on contrasting wave speeds between the targets and the surrounding soils so objects such as clay drainage piping or PVC can be much more difficult to detect than a metallic object.

Depth Expectations in soils will vary, 2-12 feet. Depth Expectations in concrete can be 18 inches or more depending on antenna frequency.
Accuracy in soils, +/- 6 inches either side of markings and as much as 15% of the total depth.
Accuracy in concrete +/- ¼ inch to either side of markings and +/- ½ inch in measured depth. This performance can vary from site to site due to soil conditions, the settings that are applied, and access to scan area.

SIM, Applied Methods and Practices

The ultimate goal of *SIM* is to combine the experienced technician with the best technologies available. The importance of experience-based training cannot be understated. The effort and experience of the individual field technician are directly linked to the likelihood of a successful project.

Summary, Experienced-Based Methods in Concrete:

- Jobsite hazard analysis performed on site and documented
- Review locations with site contact
- Understand the scan goal. What information is needed by the client.
- Understand the details, slab thickness, anticipated structural reinforcement, potential for nonstructural elements and potential hazards on site
- Prove out the information given by the client with GPR
- Visual inspection under suspended slabs
- Use multiple antenna frequencies on slab on grade applications for safe trenching
- Confirm no energized conduits
- Mark tops and bottoms of metal decking
- Isolate conduits through cross-polarizing

Summary, Experienced-Based Methods for Underground Utility Location:

- Jobsite hazard analysis performed on site and documented
- Perform site walk with site contact to review scope of work. Visual signs of utilities in the area are noted for investigation. This includes areas outside of the zones marked as scan areas
- Access to exterior and interior utility areas like mechanical rooms, pumping stations, and power duct banks is requested
- Design and As-Built drawings are requested for review
- Checklist of all utilities known to be at the site, informed of by site contact, or observed by visual walkthrough
- Performed active sweeps with RD. Note: never connect to any electrical wires
- Performed passive sweeps with RD with both Power and Radio modes.
- Used GPR to perform evaluation scans to determine average depth of penetrations and adjust settings accordingly (gain levels, depth range, dielectric, etc.)
- Performed scans in both directions sufficiently covering work area
- Marked anomalies within scan area
- Position marking flags if needed and with client permission every 20’-30’
- Used traceable rodder for known sewer and storm lines that were not yet located
- Walked site and reviewed findings and concerns with site contact

Conclusion:

Construction activities such as excavation, concrete cutting, and coring have inherent risks of health and safety as well as property damage. The goal of a subsurface investigation is to reduce these risks and create a safe and efficient working environment. This paper details the investment in developing people and using the best technologies to gain the best results.

The two assets alone, human and technology, are not enough to achieve an exceptionally low level of line strikes. *SIM* represents the blending of the ability of the field technician to solve complicated puzzles utilizing accepted industry best practices and available technologies. Thus, Subsurface Investigation Methodology (*SIM)* is where experience-based training is combined with the right investigative technologies.

Please visit www.simspec.org for more information and detailed SIM specification.