Society of Gas Operators

NIL NISI BONUM

October 16, 2014

A Discussion on Remote Sensing and Mapping

USRADAR INC.

SUBSURFACE IMAGING SYSTEMS

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Subsurface ~~Utility~~ Detection

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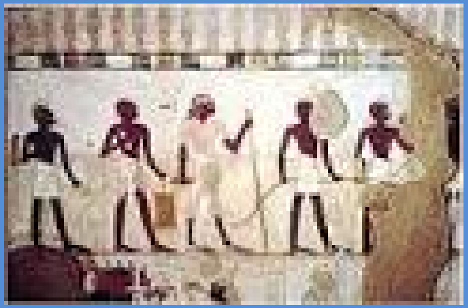
Subsurface Everything Detection

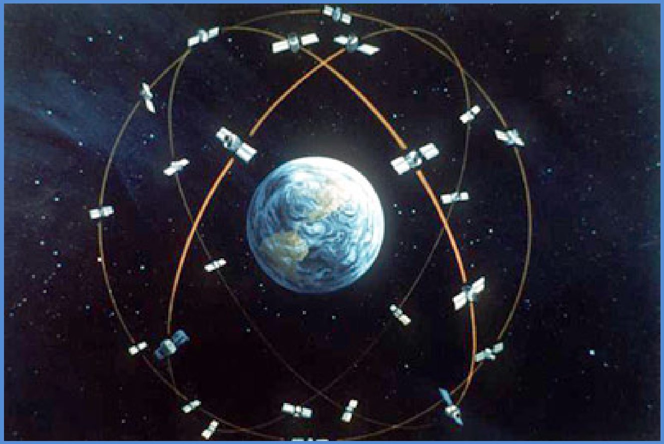
(and mapping what we find)
Taking it to the next level

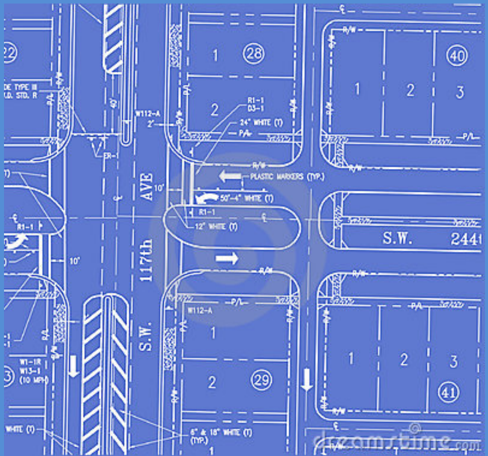
If it’s visible at surface level, it can be mapped

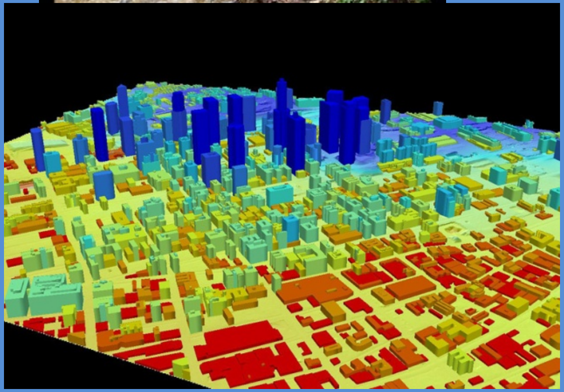
Over the years, it’s been figured out.

Let’s ponder how it’s evolved



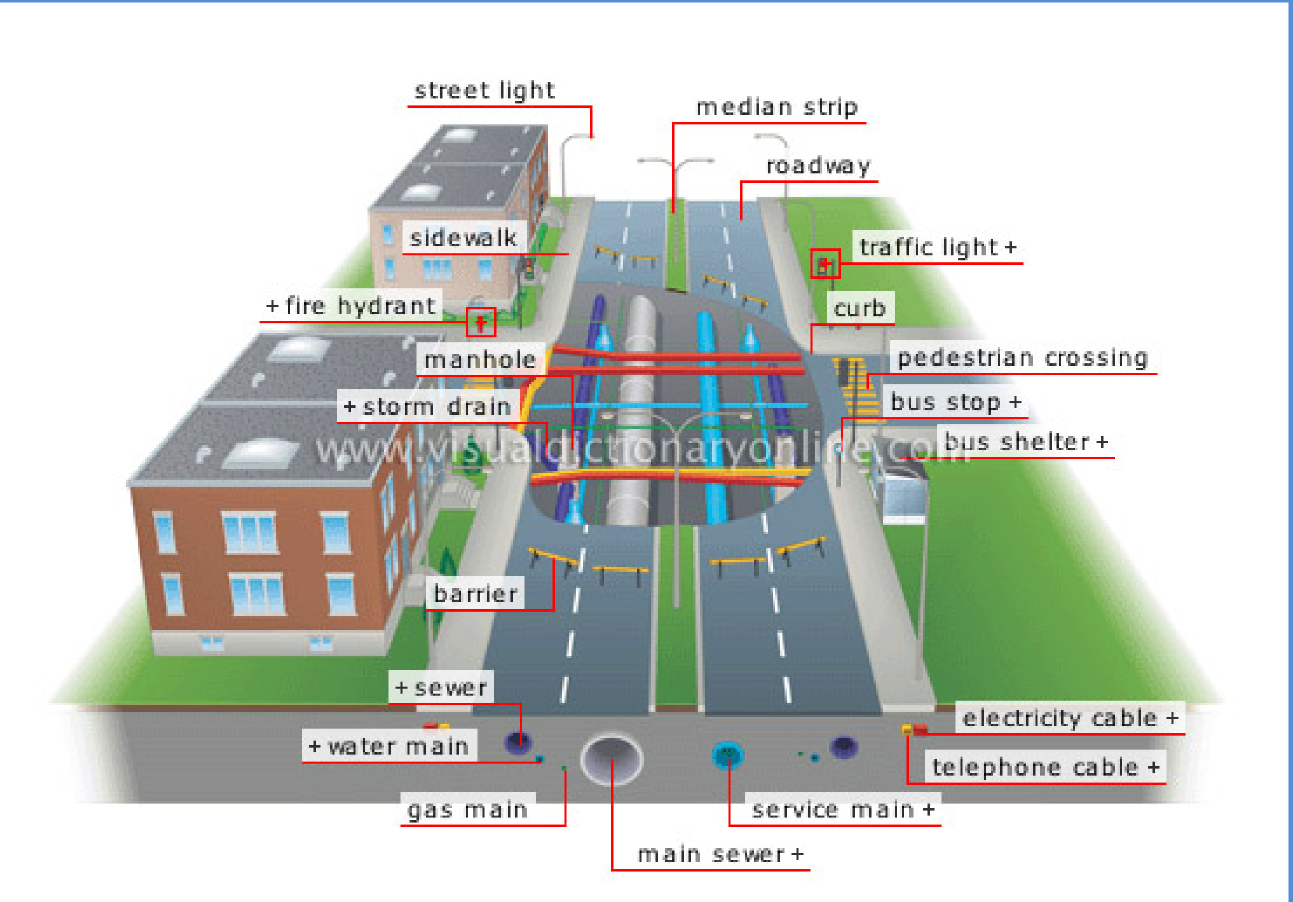






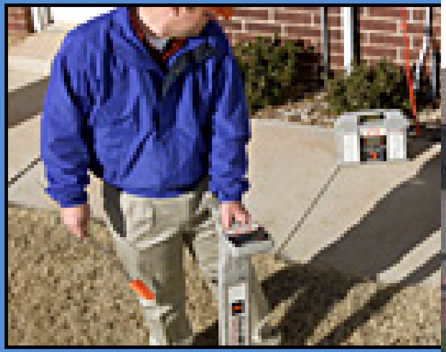
So now we're figuring out how to map what some surveyors and engineers have called… "the final frontier"

Remote Sensing
The name of the game is accurate detection, and accurate mapping of the findings…

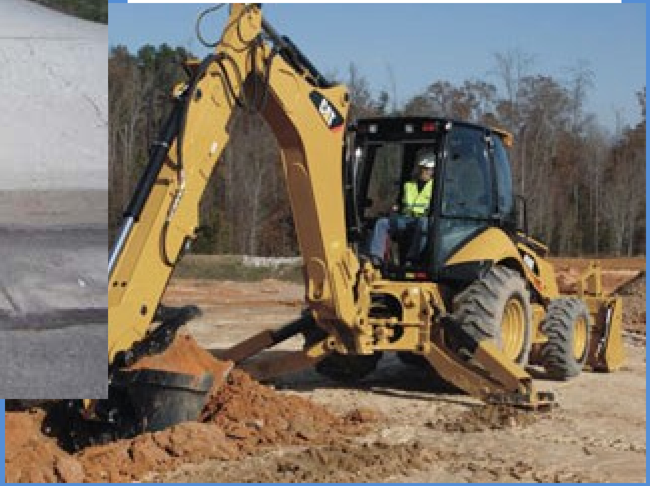


Non-destructively…

Locating Technologies







With today’s technologies available to you, it really helps to throw as many technologies as possible at the “problem”.

Using multiple technologies gives you the ability to increase your detections and confirm findings as well

There are some better options

Why Radar?

•As we advance digital capabilities, todays radar systems have come a long way in imaging capability, and user friendliness

*Current Radars are very easy to use

*Radar is easily deployed

*Radar complements many other technologies

*Radar is non-destructive

*Radar has a wide array of applications in detecting objects both conductive and non-conductive

GPR Technology Capabilities

- Detect all types of pipes i.e. cast iron, clay, steel, plastic, asbestos cement (transite), ductile iron, even wood pipes!
- Identify Asphalt and Concrete Limits and Thickness Illegal or unknown connections
- Identify paths for future installations
- Locate missing valves
- Make sense of complicated networks
- Identify Rock and boulders prior to excavation
- Locate Buried Power Cables
- Locate Buried Splice Locations
- Locate Stub-outs and empty conduit
- Detect previous excavations
- Detect cables and Fiber Optic lines

<u>Types of Pipe</u>

Clay Pipes
Plastic or PVC
Concrete Pipe
Transit Pipe
Metal Pipe
Conduit
Cable or Wire
Manholes
Water Boxes
Abandoned Lines

Radar detects changes in the medium under investigation. Air Traffic Control radar are stationary, tracking targets that are moving. The moving target or aircraft is the change in the field of view that the radar easily tracks.

The operator monitors the screen and the objects as they move through the field of view of the radar

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The principle behind the radar image is that we are watching for objects that are different from the surrounding material.

In the case of Air Traffic Control Radar, the aircraft is of a totally different composition than the airspace and will show up as an anomaly

A raincloud is completely different from the surrounding blue sky and will show up as an anomaly.

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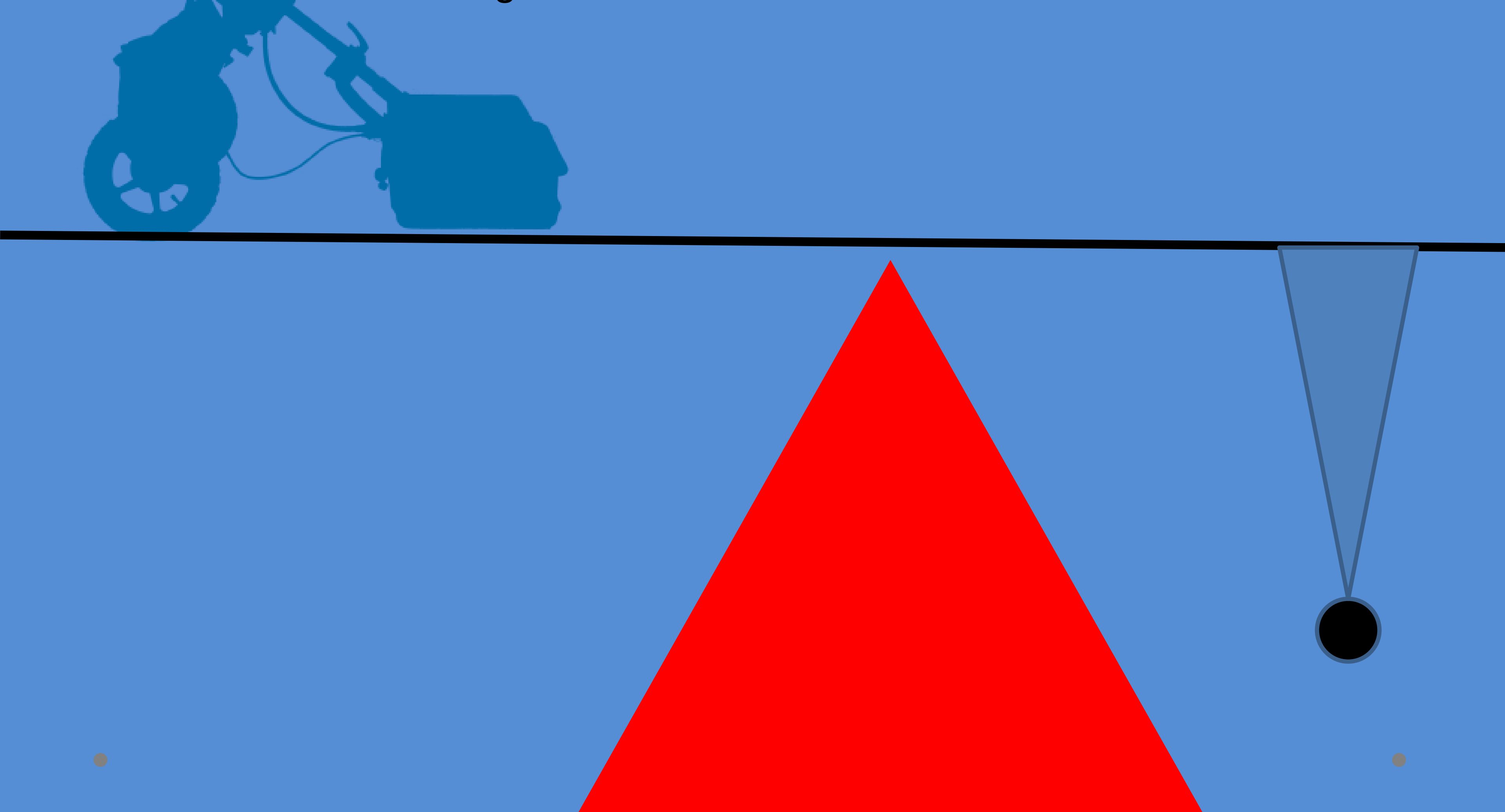
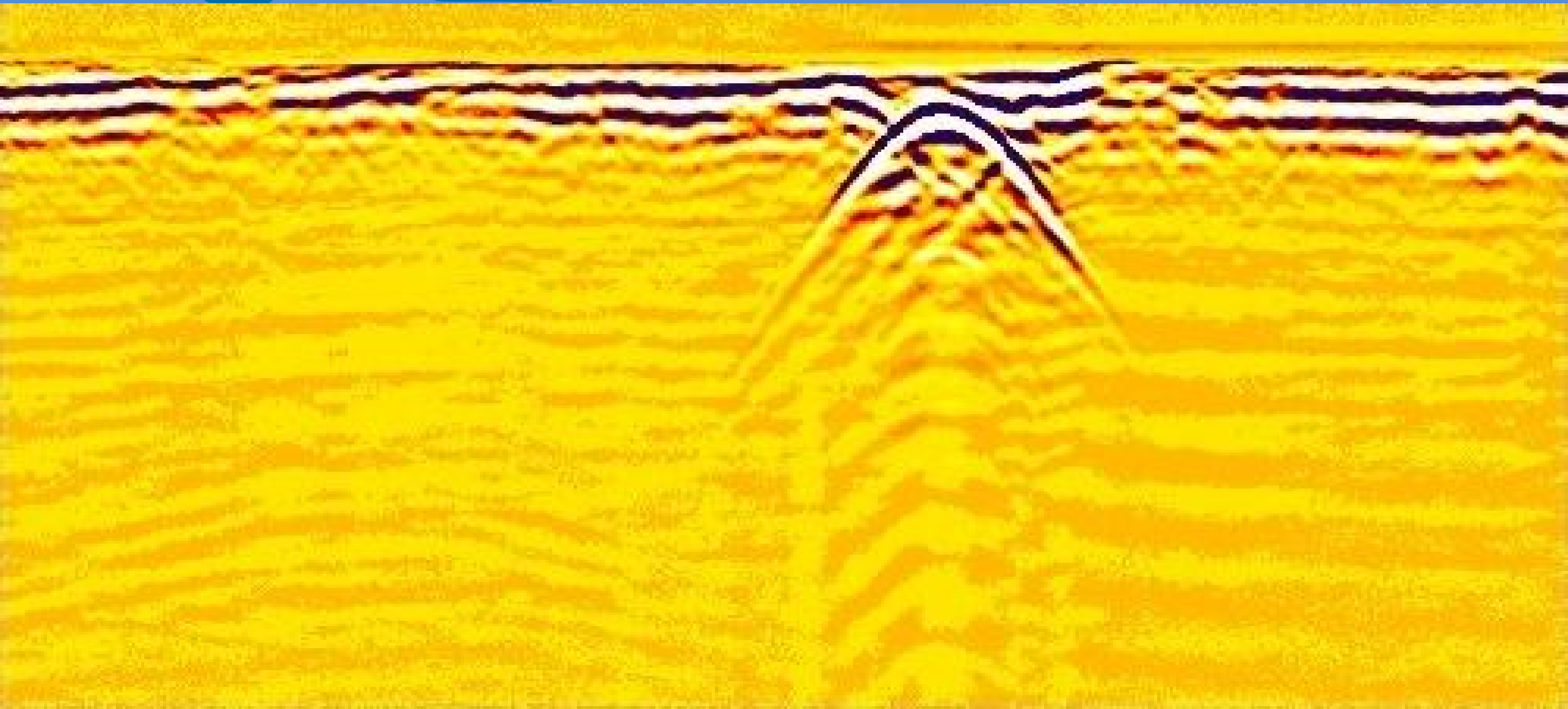
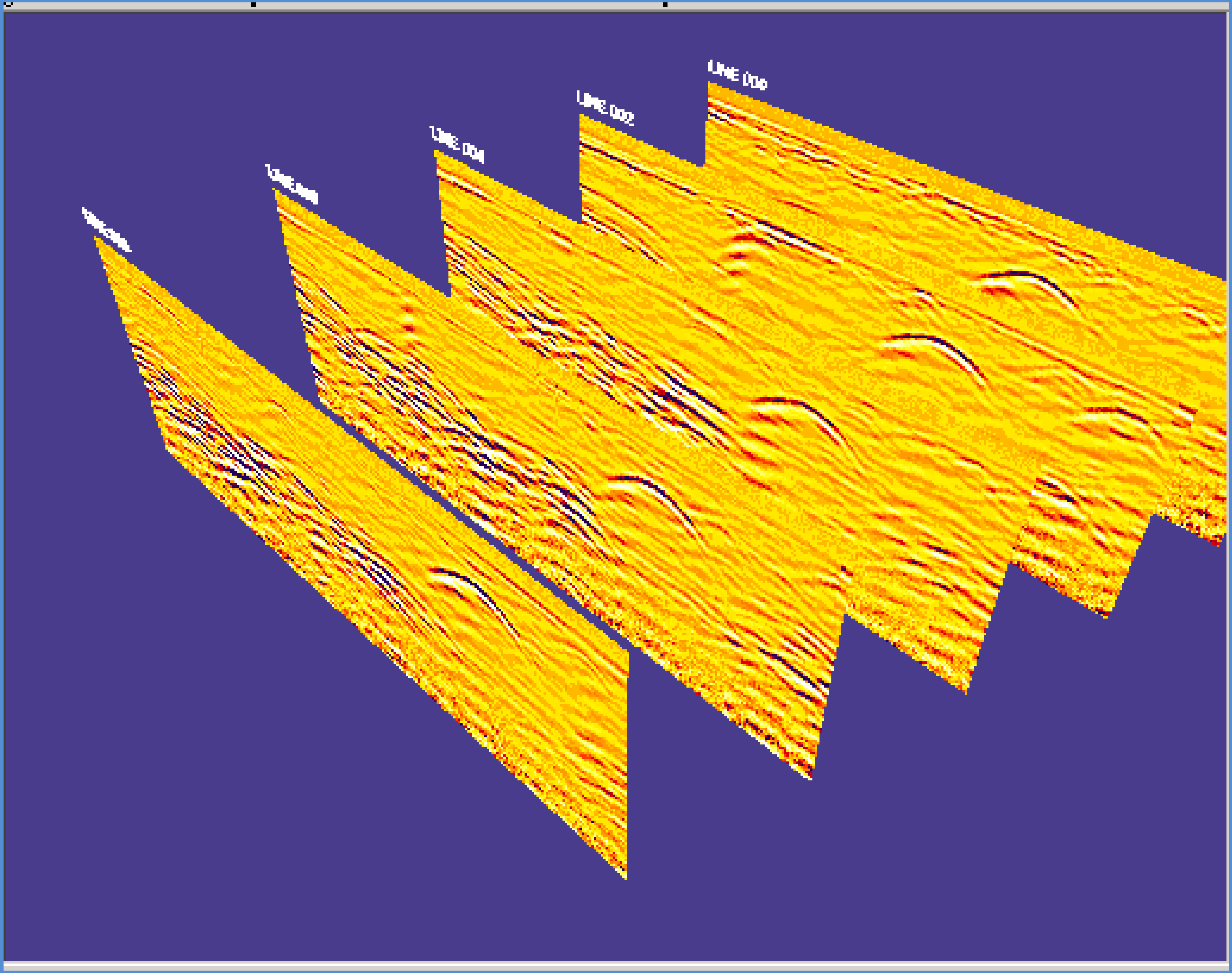
The GPR sends radar energy into the investigation medium at the centerline of the system in the direction of travel. When a target is encountered, the energy is bounced back and an image is created.



Images are created as cross sections or “slices” in the direction of travel



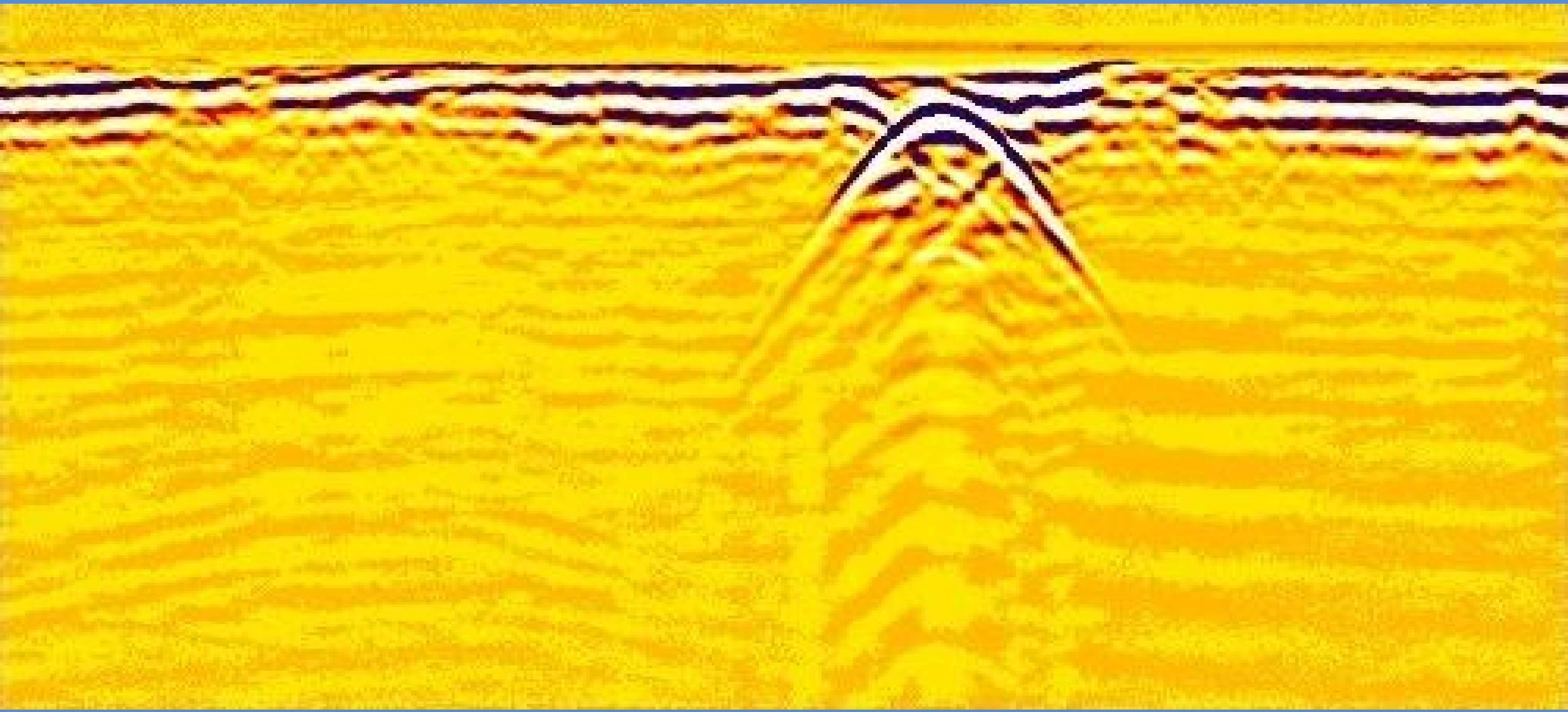


Cross Sections or Slices across the width of a road

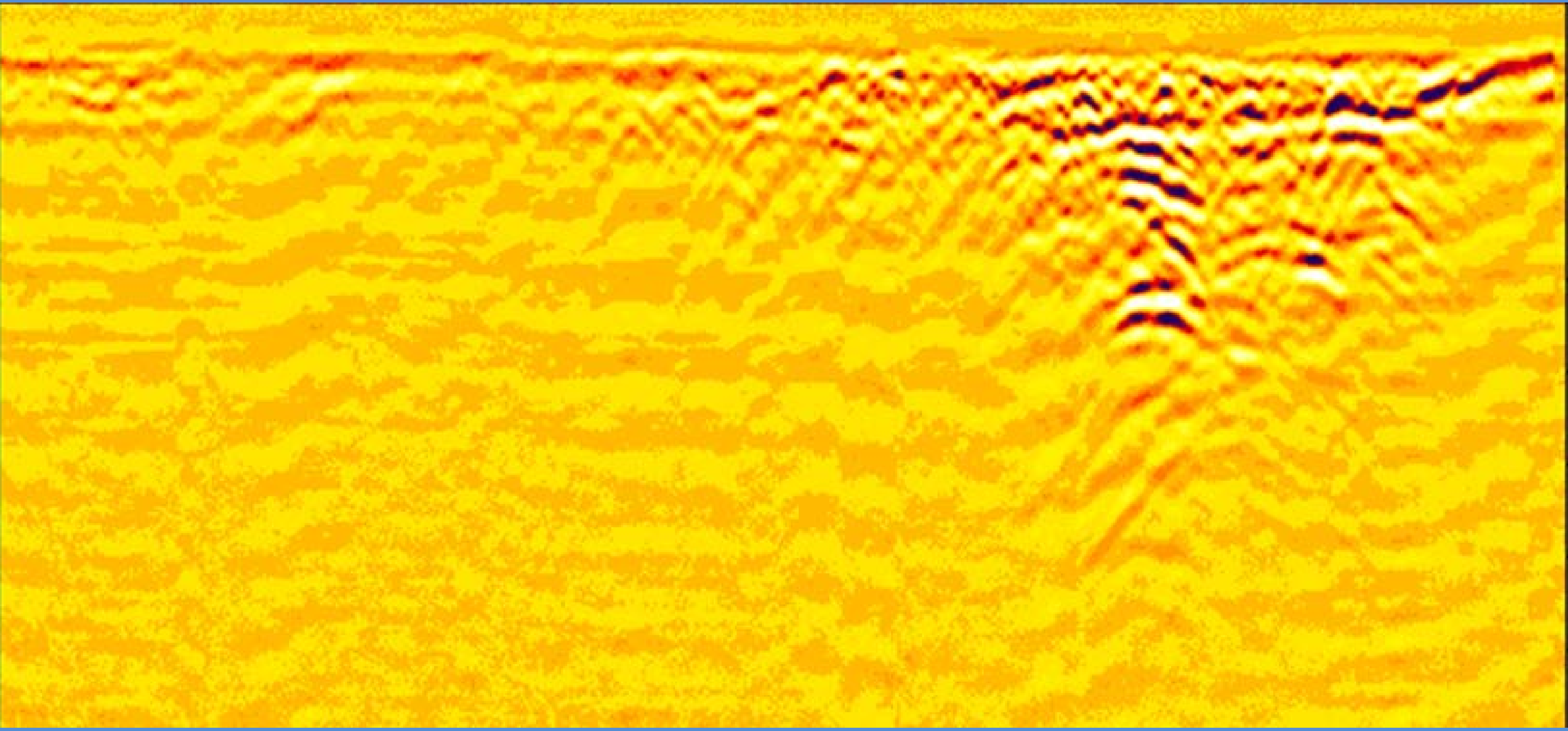
Keep in Mind that we are sending out radar “Pulses”

These pulses if they could be seen, would appear to be waves similar to waves coming in to a beach

What happens when waves encounter an obstruction i.e a boulder in the way ?

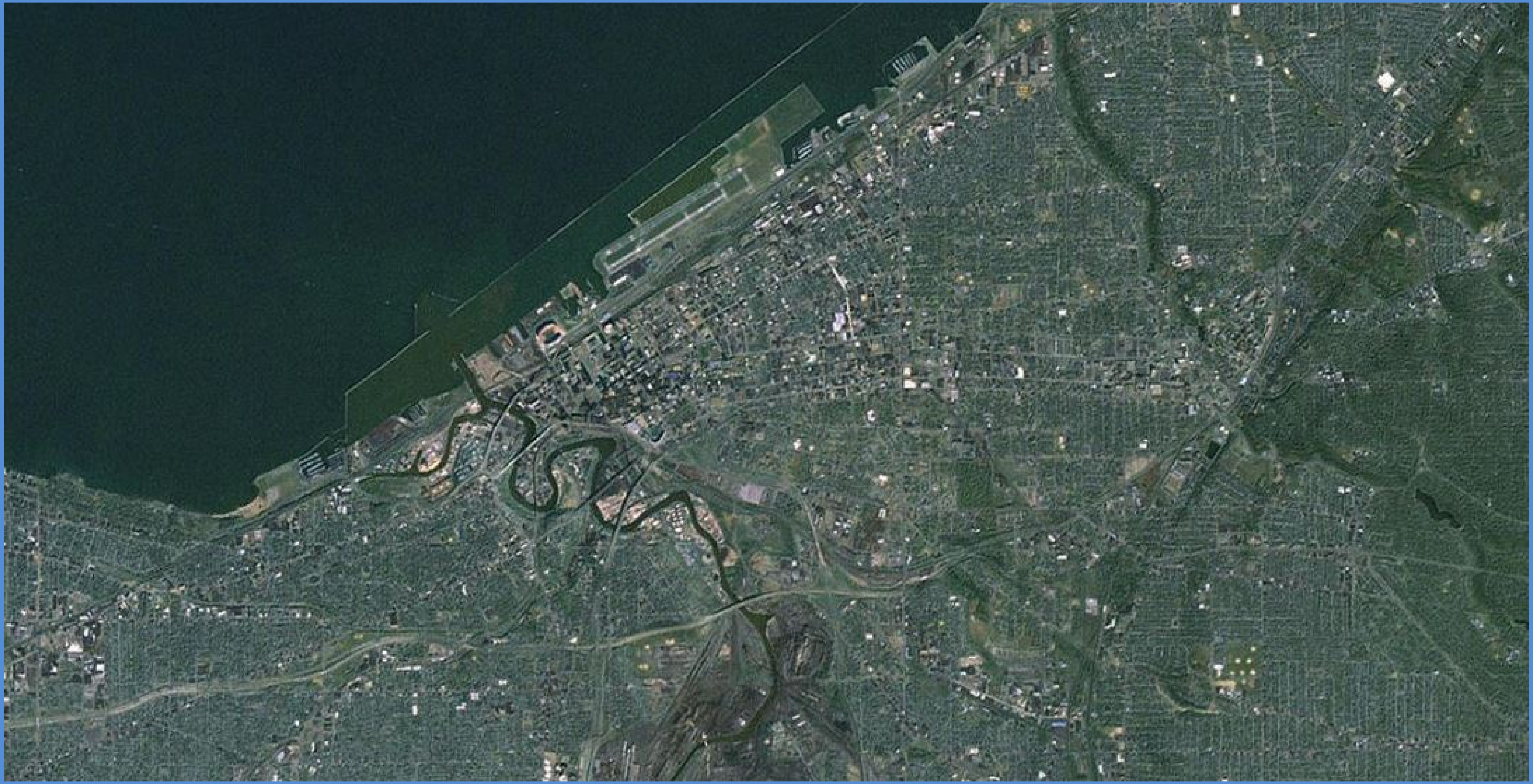


So what happens when waves approach an inlet i.e a path of lesser resistance?



The Challenge

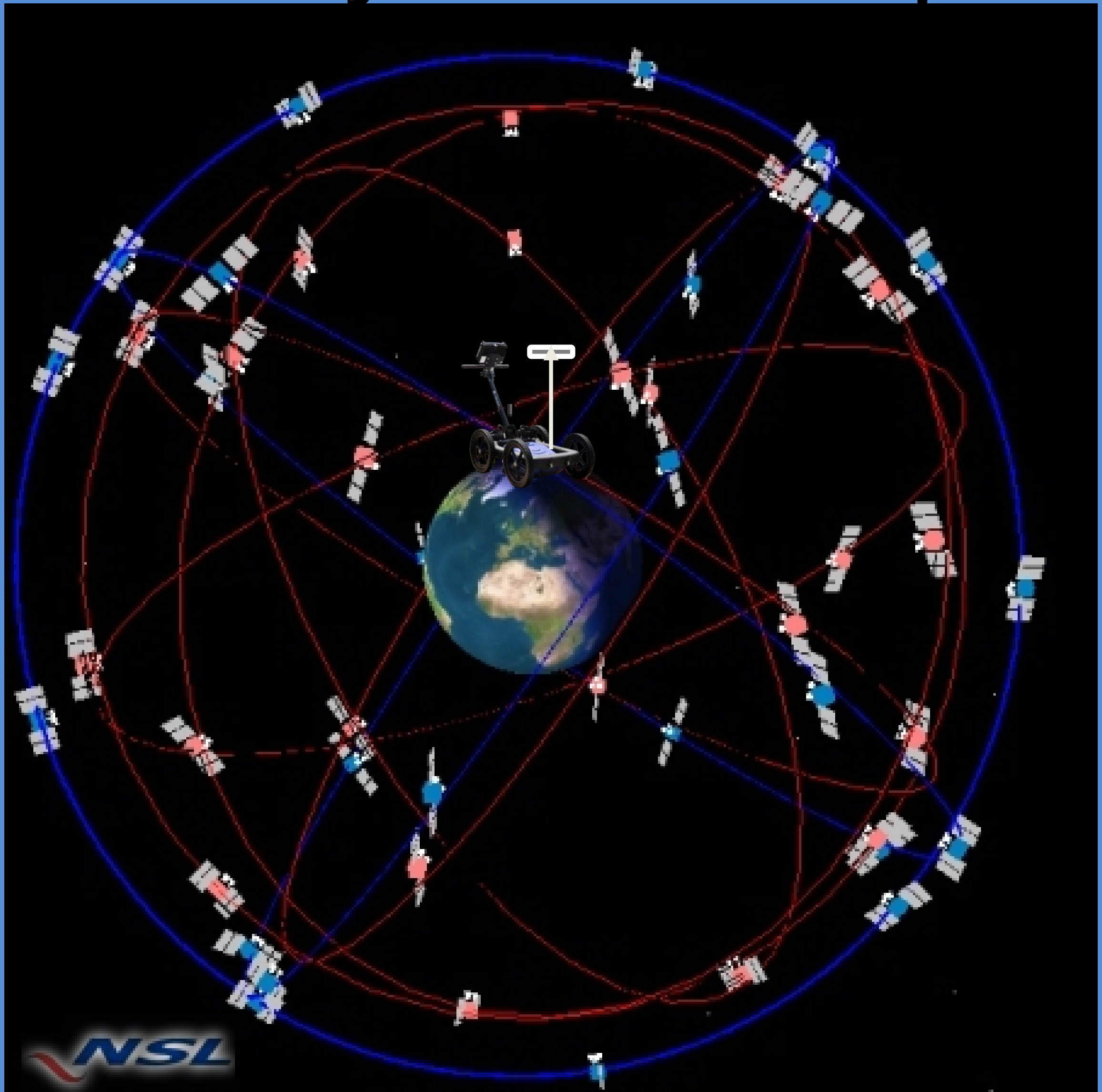
How many thousands of miles of unmapped utilities lie beneath the city?



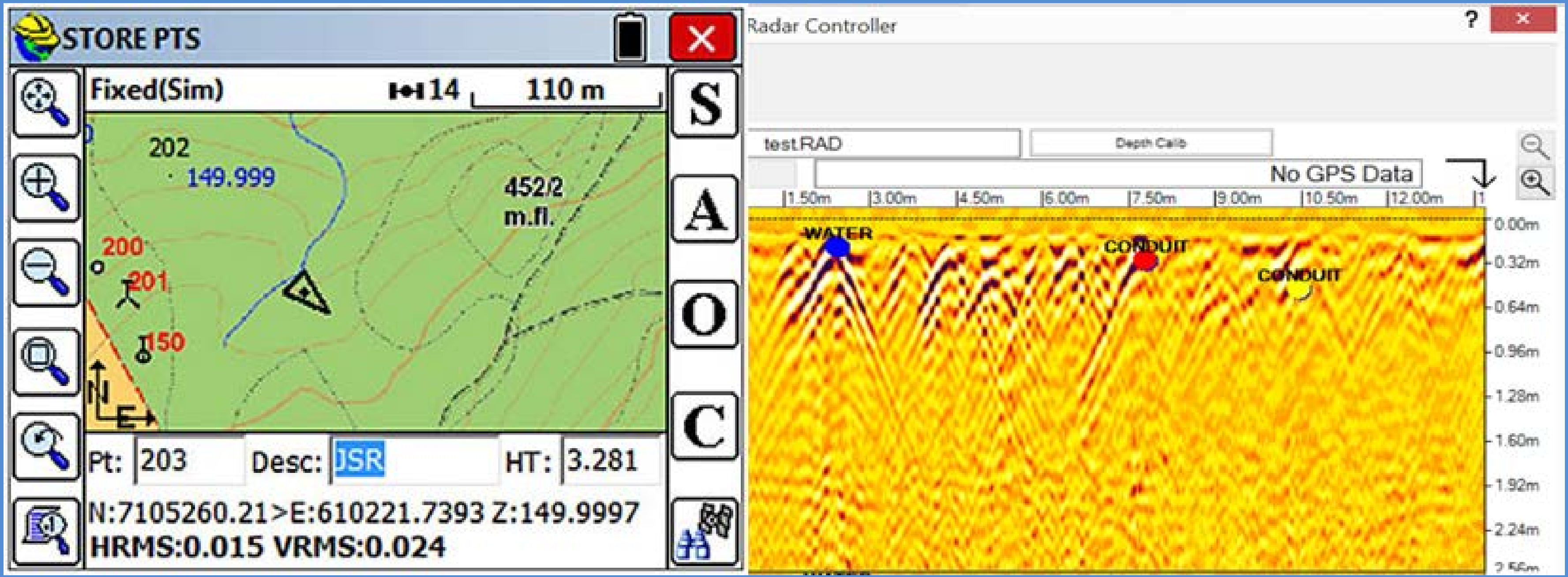
This is How it Starts

Then the “Artistes” Move in

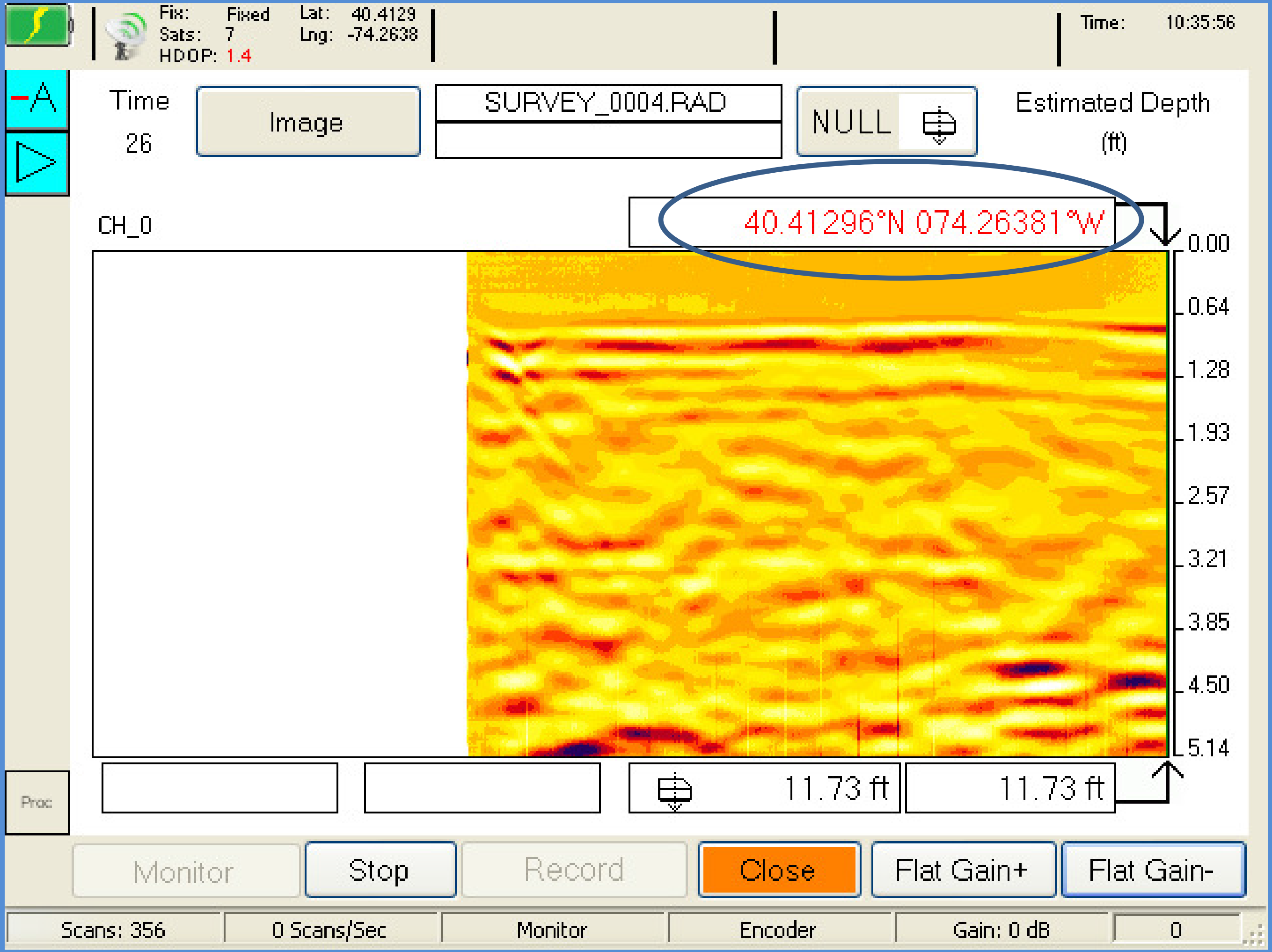
What if we combine technologies and walk away with a map?



What if we combine technologies and walk away with a map?

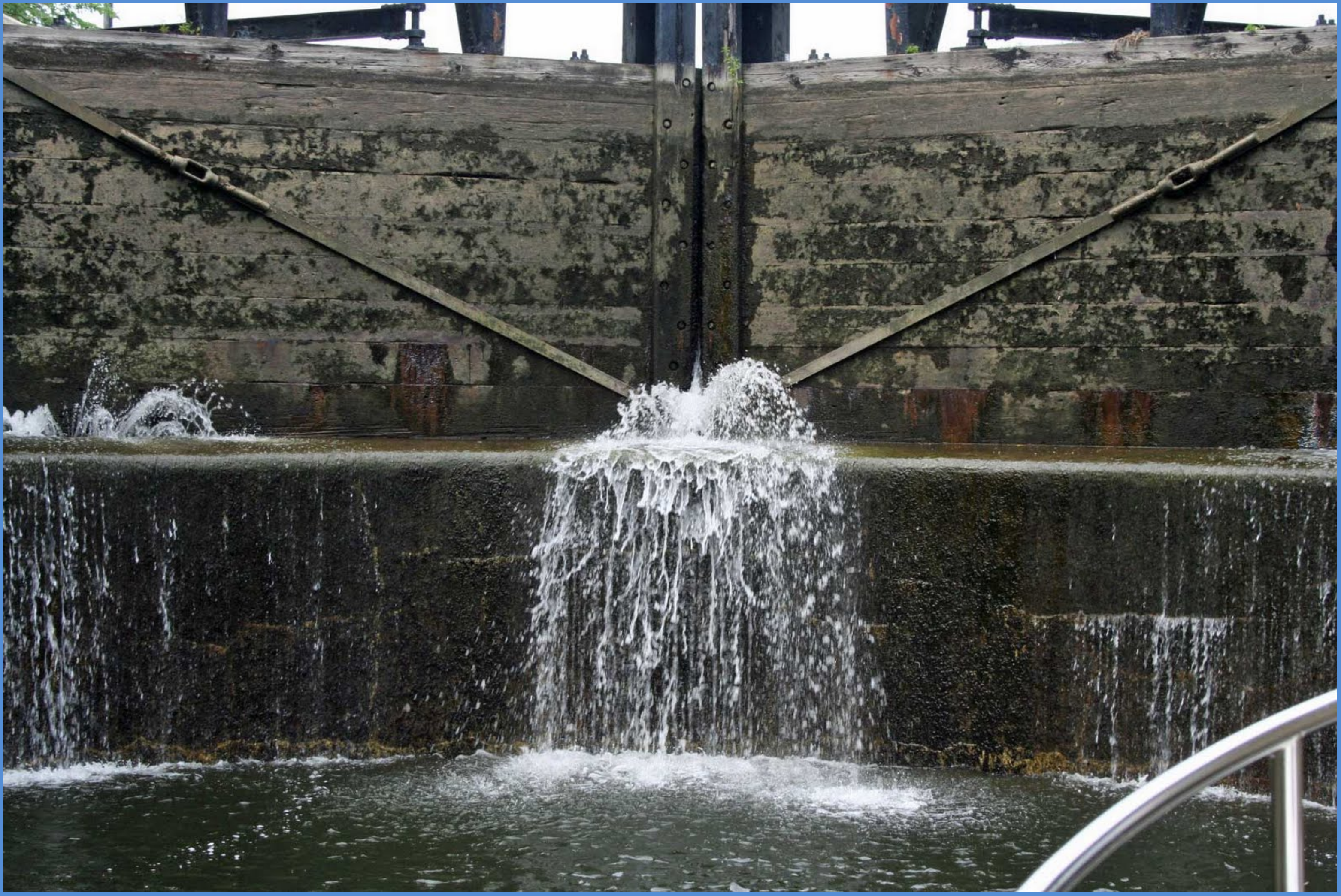


By connecting GPS, we can generate parallel files, the coordinates and the radar data

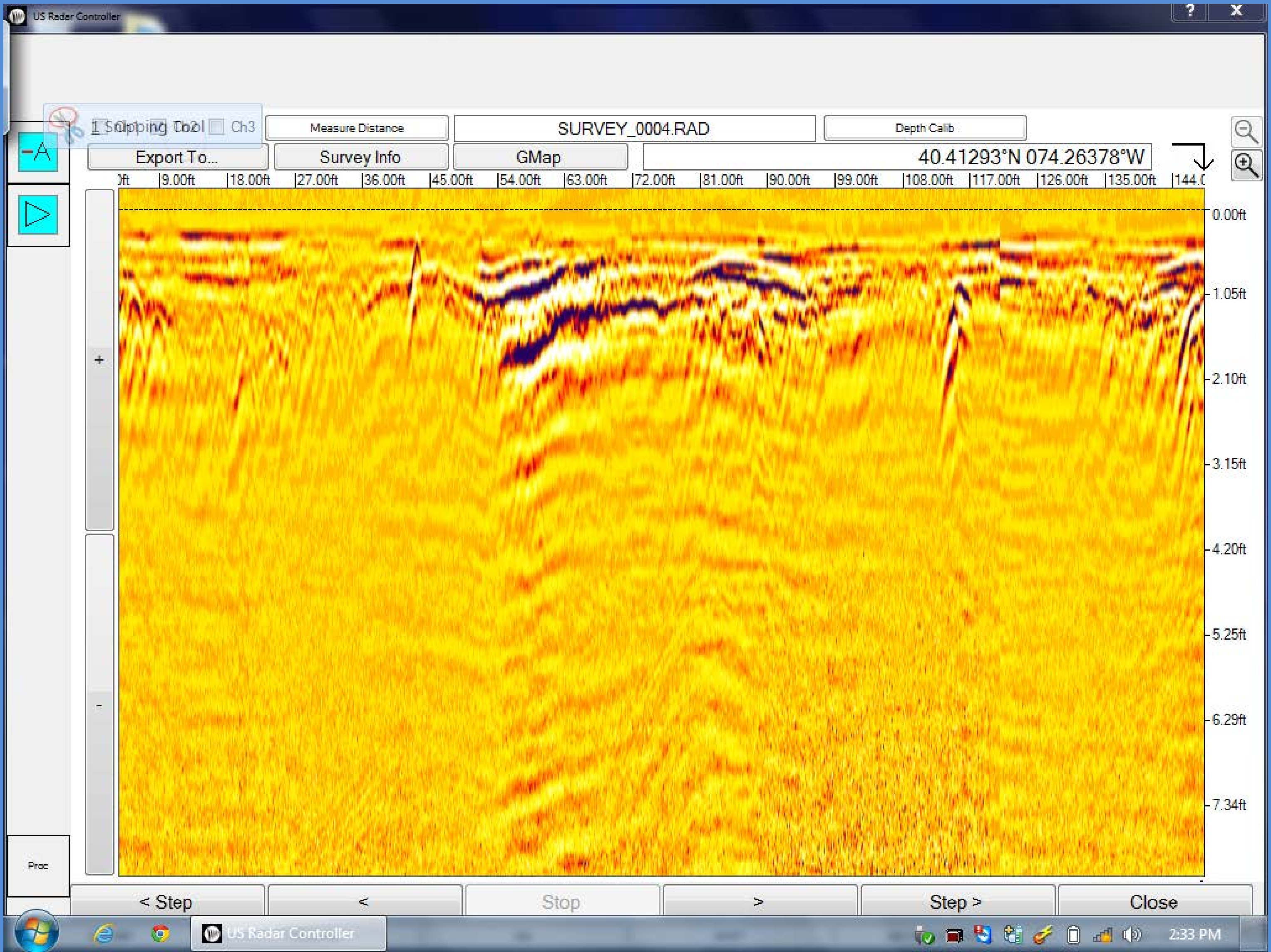


In the past couple of years we’ve made a quantum leap moving a great deal of processing to digital from analog processing, (radar energy is inherently analog)

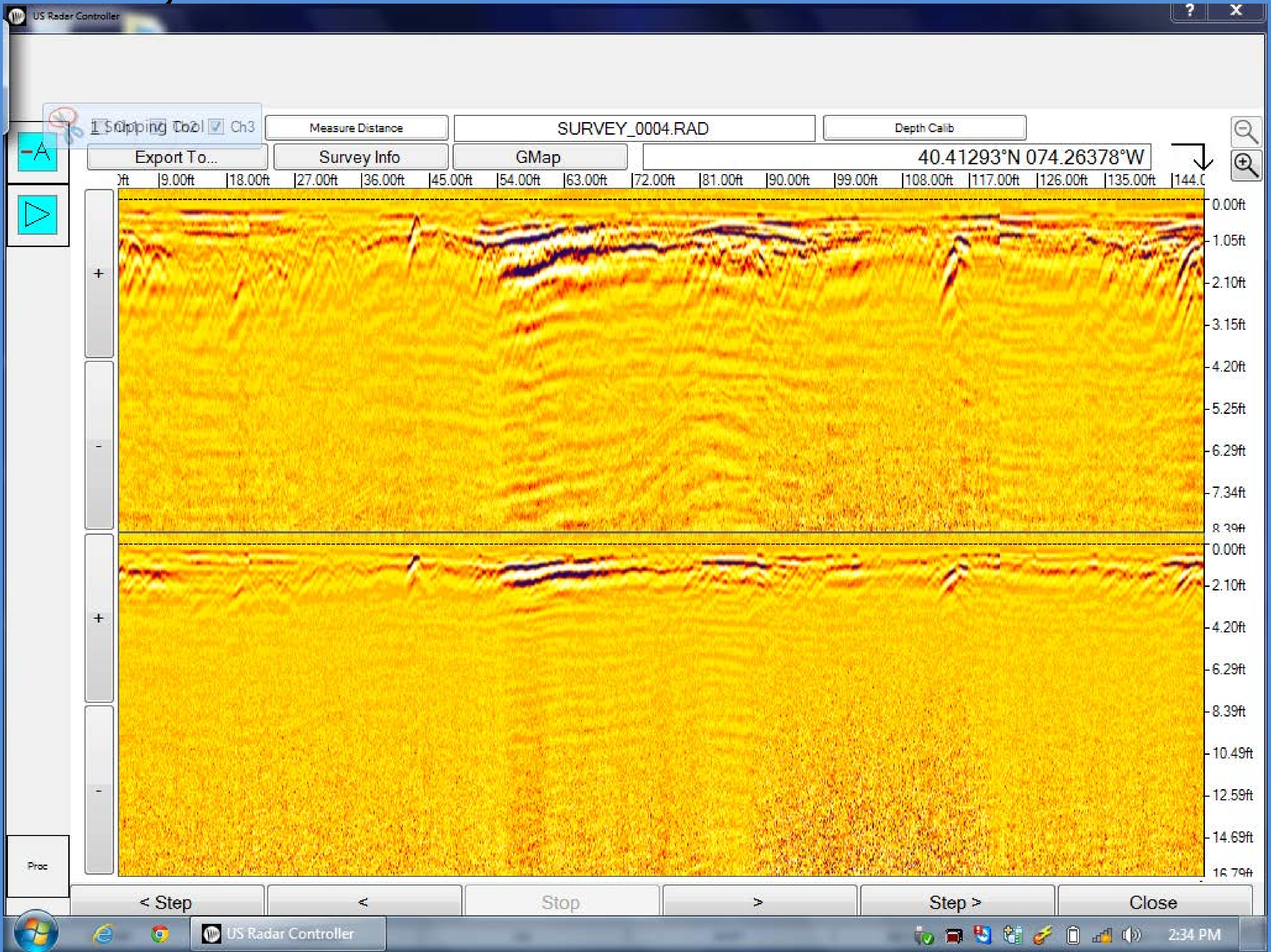
The floodgates of capabilities are creaking opening



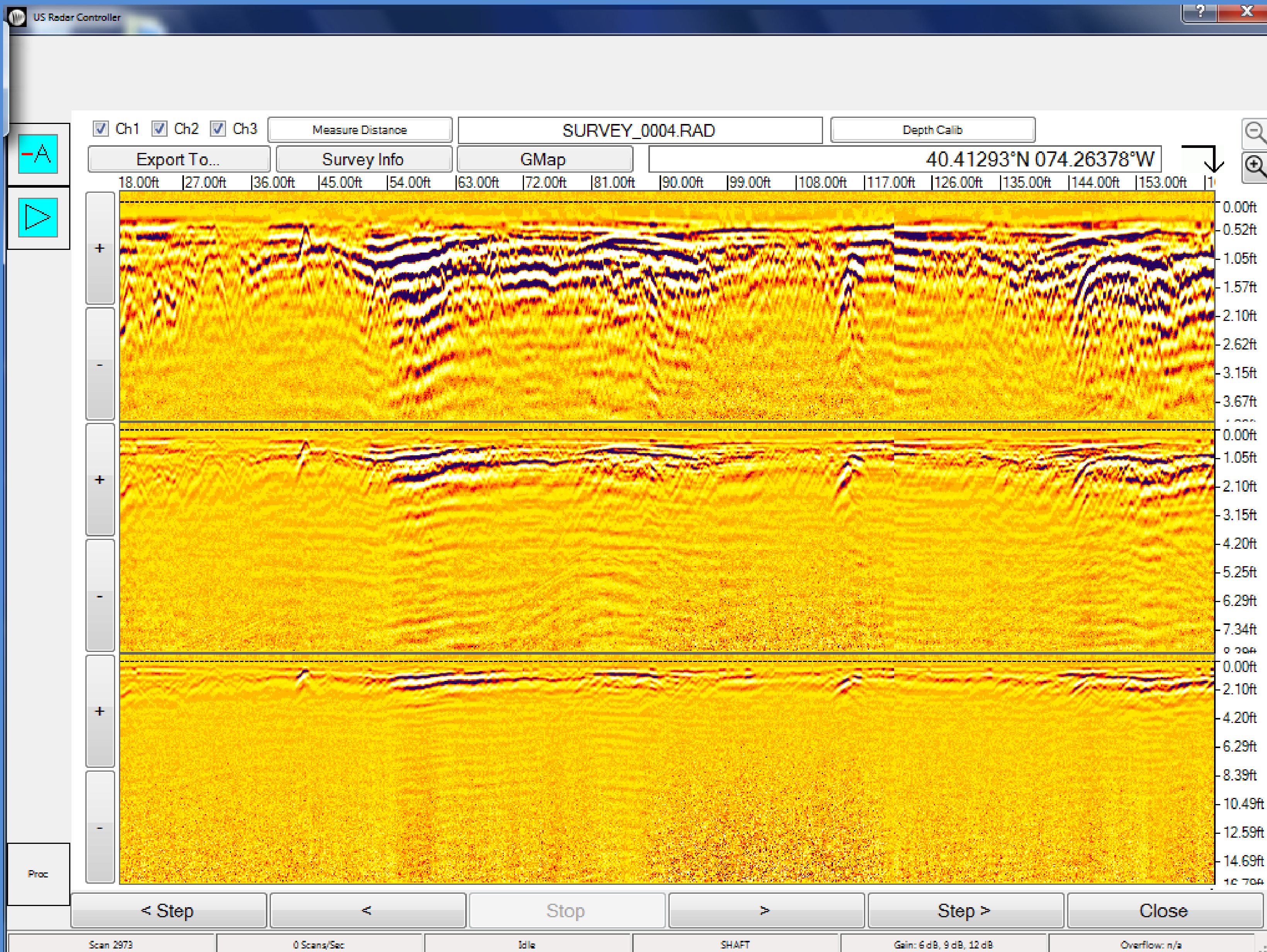
We're all familiar with single channel data



Suddenly we can add another real channel…not simulated



Oh what the heck…



So what are we doing and what is the advantage?

- GPR Antennas operate by transmitting a burst of Multiple frequencies of radio energy.

100 MHz	250 MHz	500 MHz	1000 MHz	2000 Mhz
50 MHz-450MHz	100 MHz – 950 MHz	95 MHz – 1100 MHz	500 MHz-2300 MHz	700 MHz-3000 MHz

- Each antenna uses a specific bandwidth from the radio spectrum

- For Example: 500 MHz antenna, the center strongest frequency is 500MHz. The bandwidth is actually from approximately 95 MHz to 1100MHz

Antenna Capabilities

ANTENNA	Dense Wet Clay	Clean Dry Sand	EX. Of smallest object located accurately
100 MHz	6m/20 ft	30m/100'	Tunnel @18m/60' 60cm/24" RCP @6m/20'
250 MHz	4m/13ft	9m/30'	90cm/36" RCP @9m/30' 15cm/6" PVC @4m/13.3'
500MHz	1.8m/6ft	4.4m/14.7'	10cm/4" pvc @4m/13.3' 2.5cm/.5" pvc@1.8m /6'
1000 MHz	40cm/16"	1.8m/6'	2.5cm/1/2" pvc @90cm/3' Wire mesh, shallow
2000 MHz	15cm/6"	60cm/2'	Monofilament fishing line

500 MHz is most versatile and covers depth of most utilities with best resolution

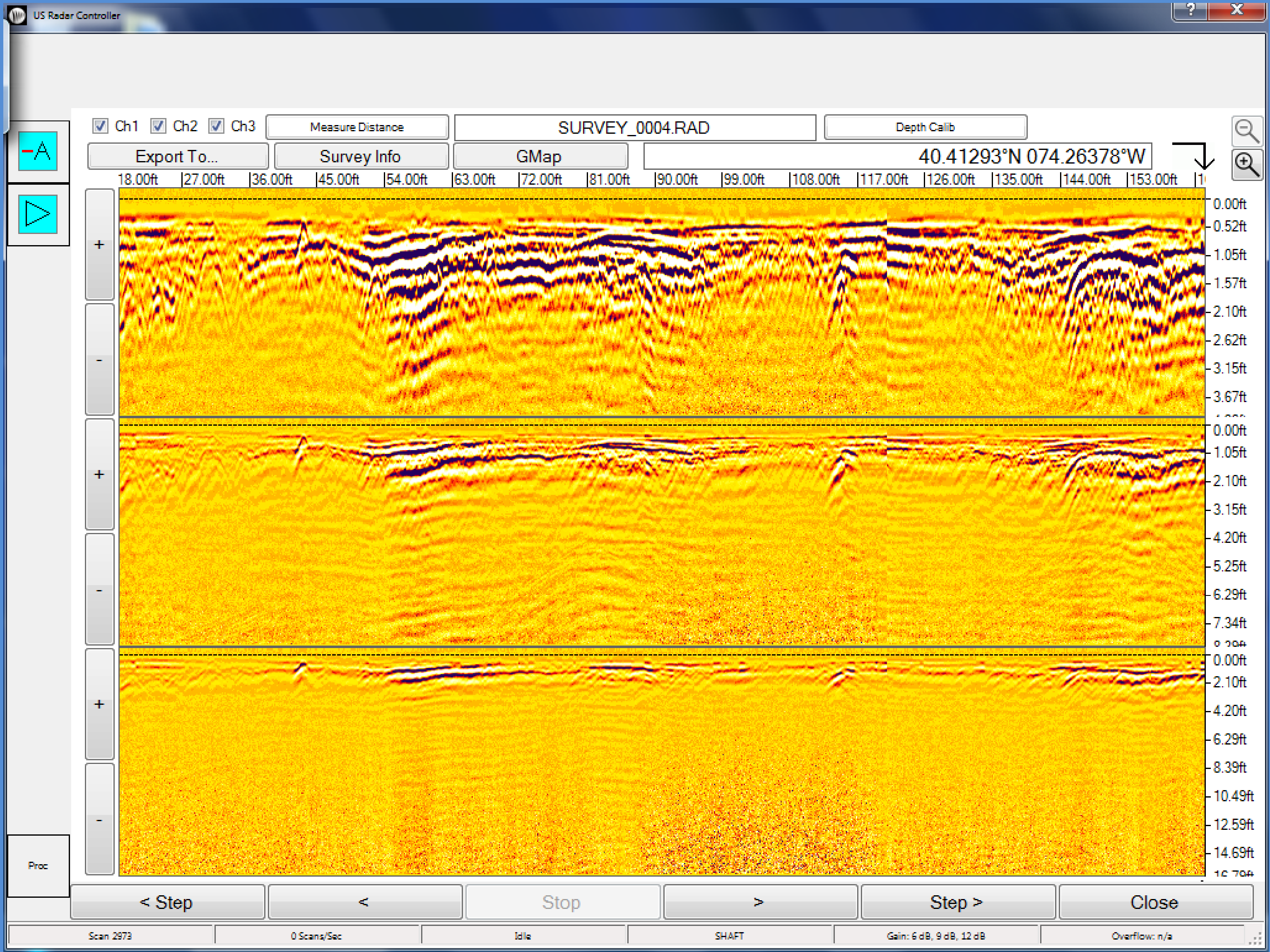
For best resolution use the shallowest available antenna that will reach desired depth,

Antenna Capabilities

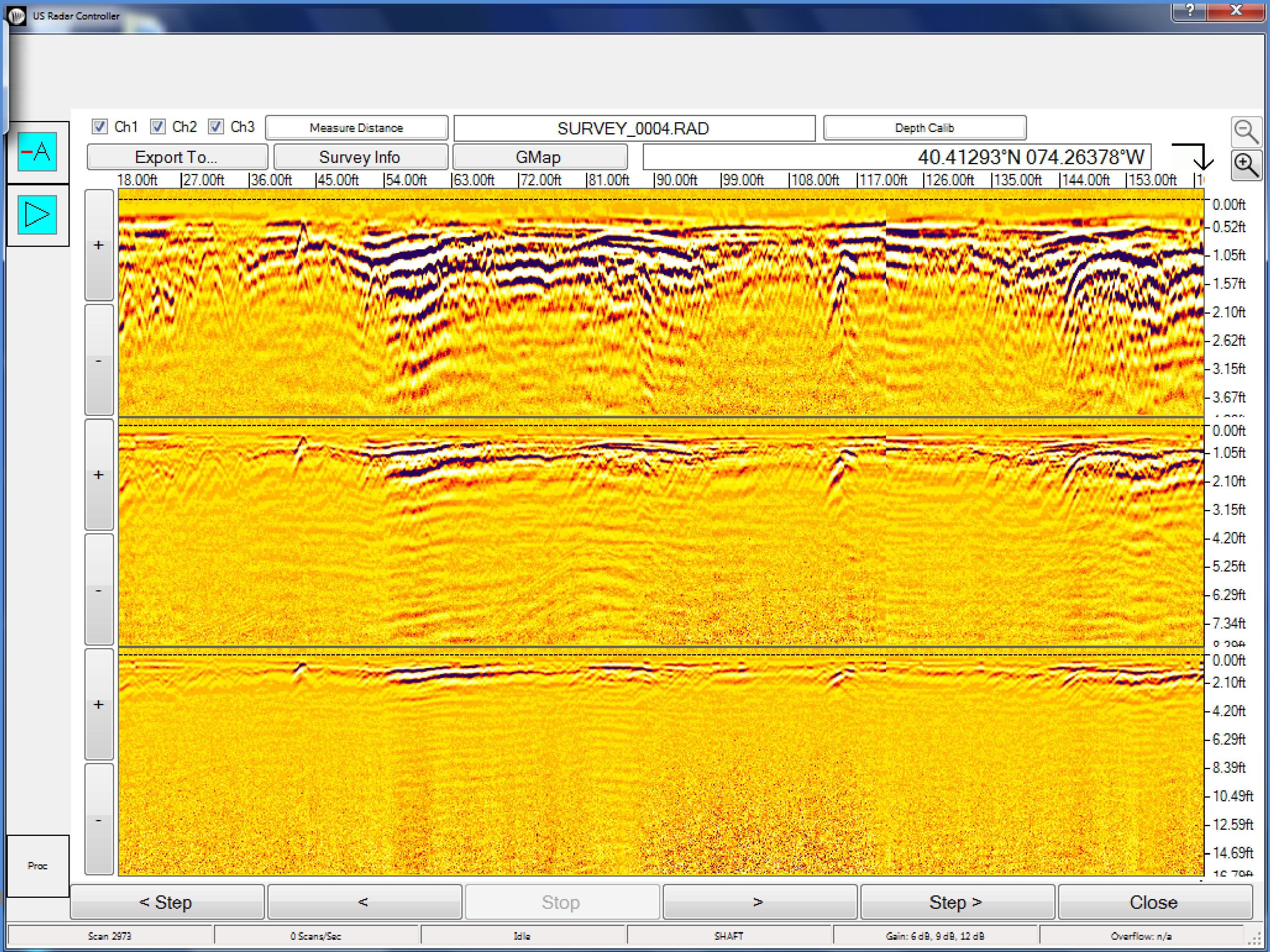
ANTENNA	Dense Wet Clay	Clean Dry Sand	EX. Of smallest object located accurately
250 MHz	4m/13ft	9m/30'	90cm/36" RCP @9m/30' 15cm/6" PVC @4m/13.3'
500MHz	1.8m/6ft	4.4m/14.7'	10cm/4" pvc @4m/13.3' 2.5cm/.5" pvc@1.8m /6'
1000 MHz	40cm/16"	1.8m/6'	2.5cm/1/2" pvc @90cm/3' Wire mesh, shallow

What if we put the 3 hottest utility locating bandwidths together in one package?

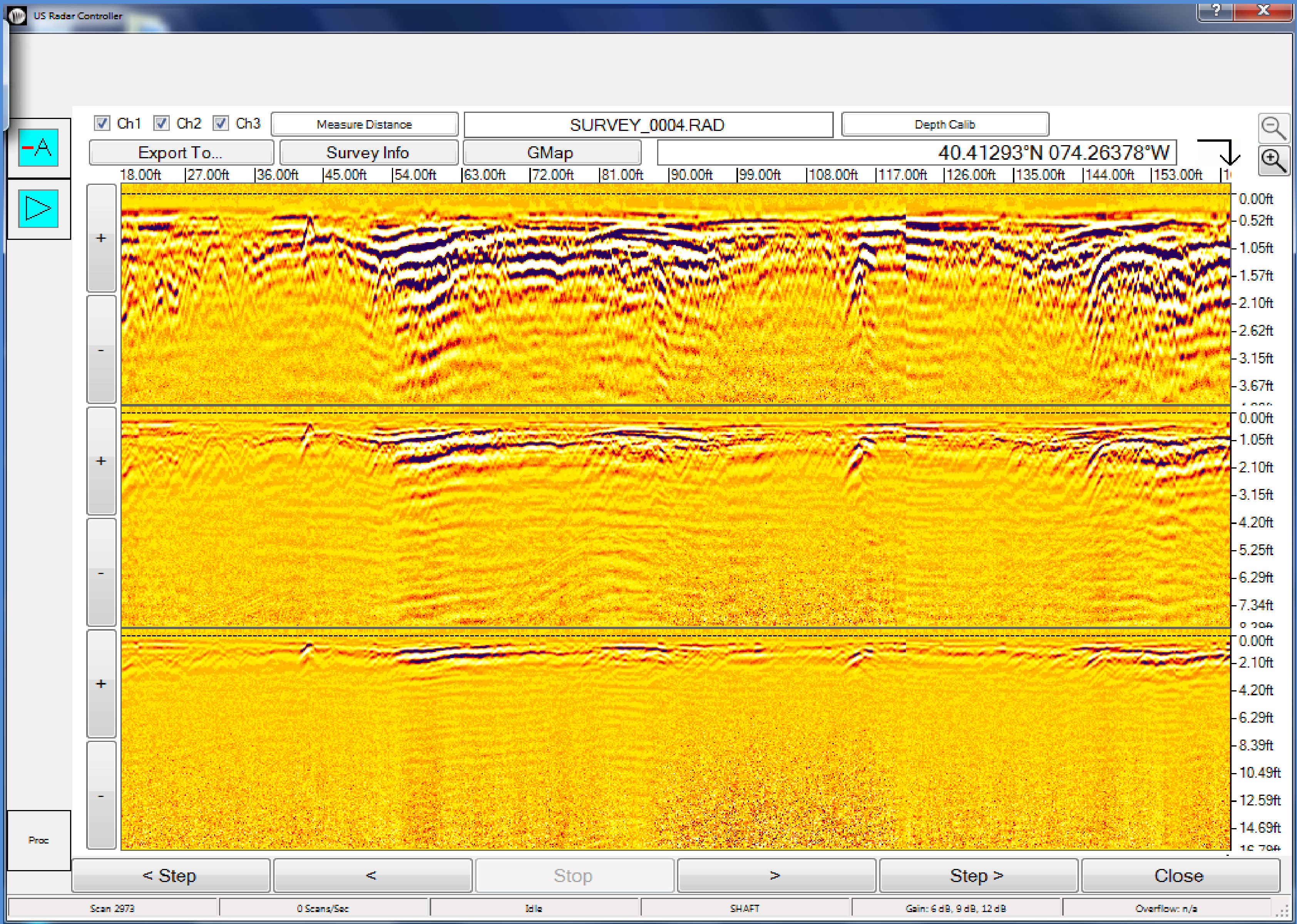
The 3 bandwidths make it very easy to recognize the most subtle changes in soil structure directing our attention toward the target



The objective is to make it easy to read and understand



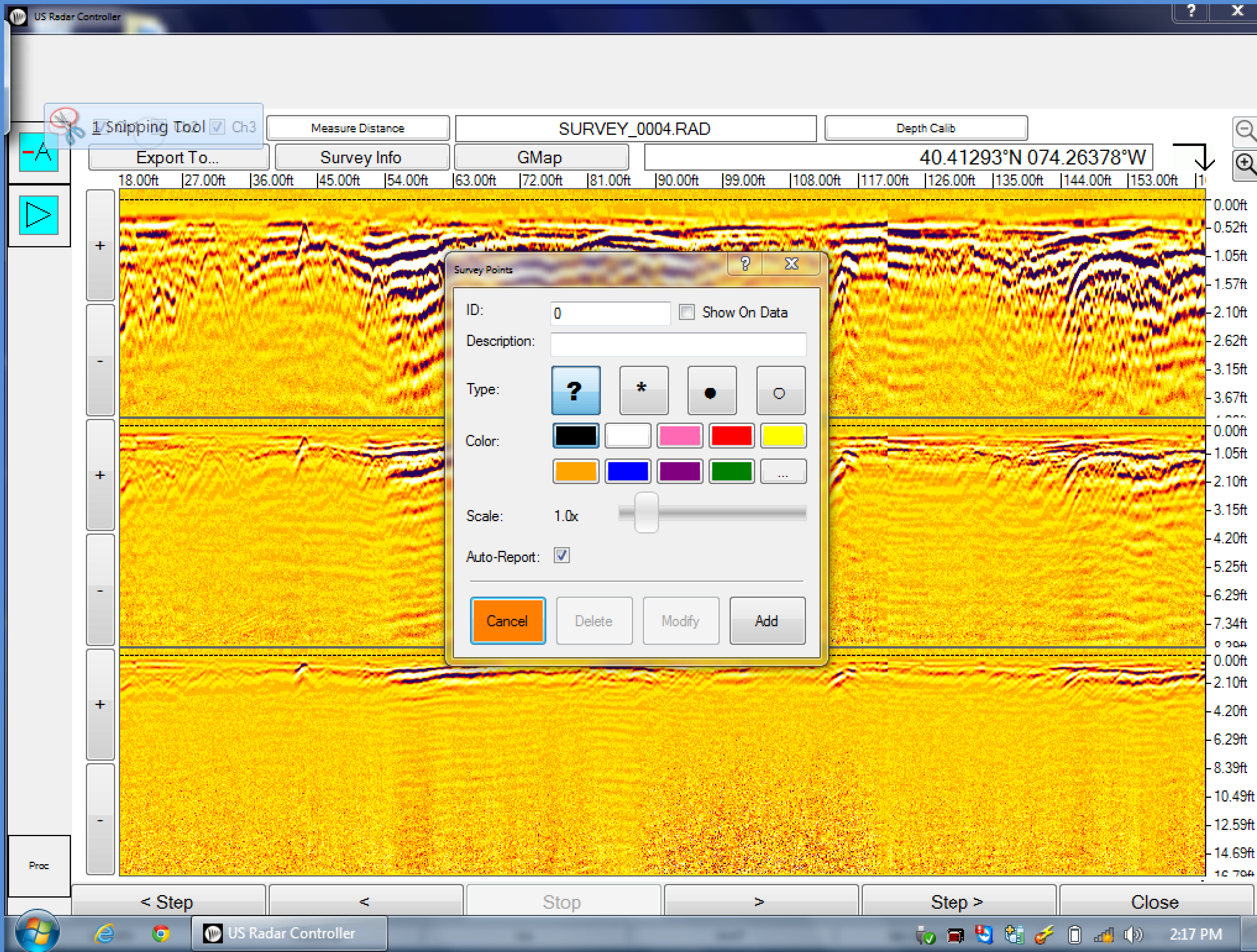
So let's do something with the findings



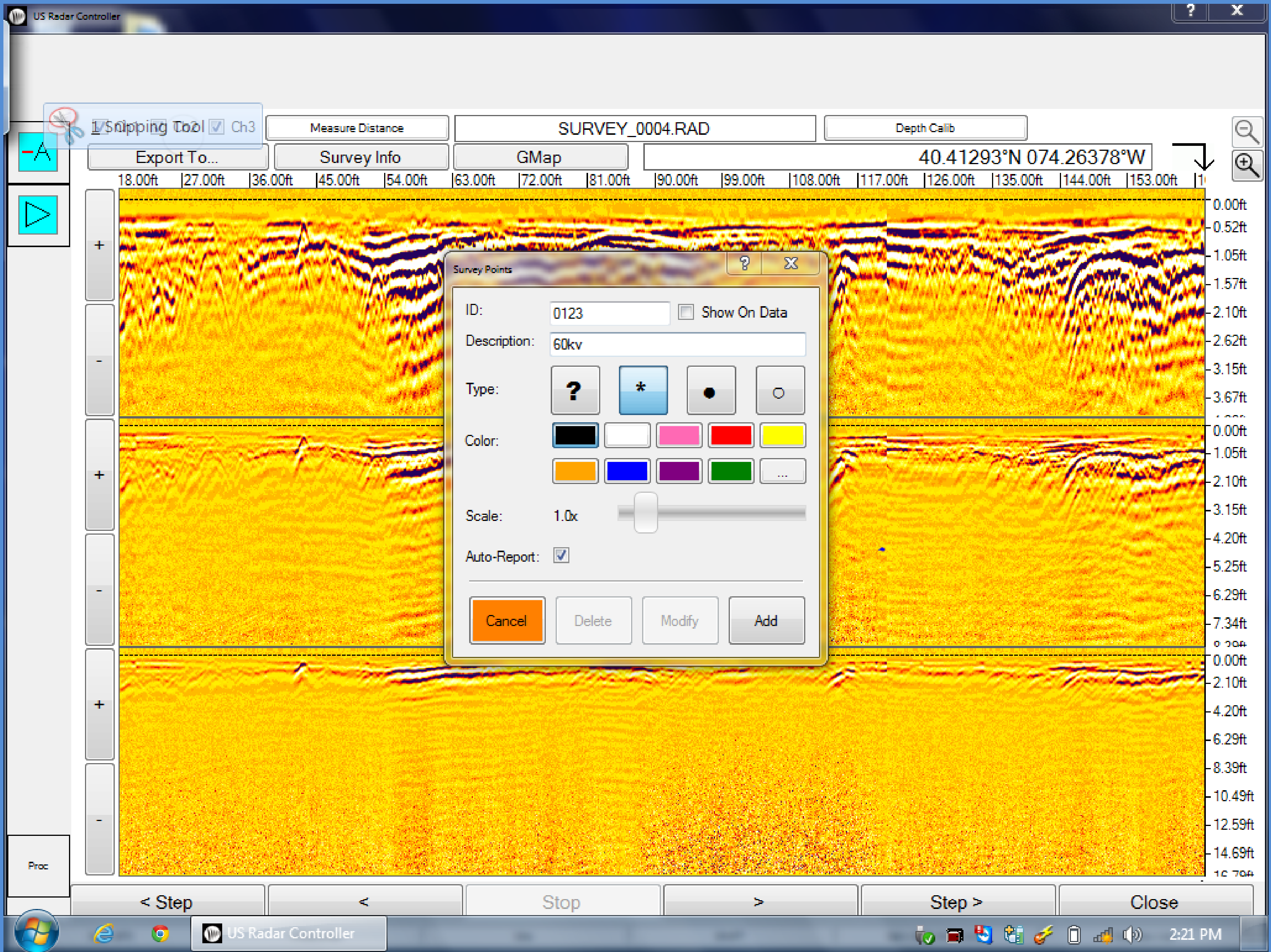
Now we’ll add a third file to our radar data and GPS

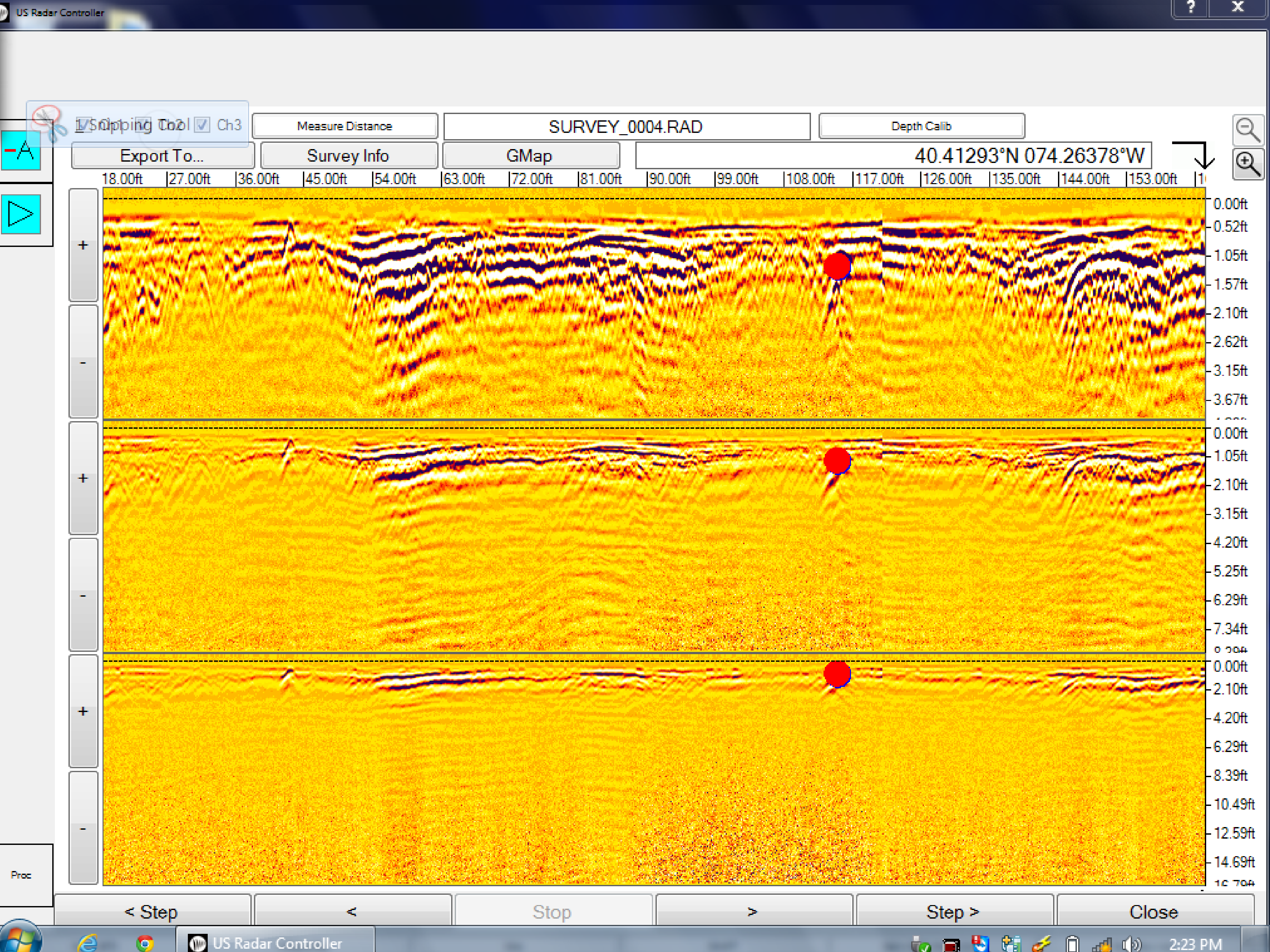
A Tag file that the operator can tag and notate targets and features in the field

By tapping the screen on a target, you can create a tag



Then we can put a point ID and description




US Radar Controller
Snipping Tool
Ch3
Measure Distance
SURVEY_0004.RAD
Depth Calib
Export To...
Survey Info
GMap
40.41293°N 074.26378°W
18.00ft
27.00ft
36.00ft
45.00ft
54.00ft
63.00ft
72.00ft
81.00ft
90.00ft
99.00ft
108.00ft
117.00ft
126.00ft
135.00ft
144.00ft
153.00ft
0.00ft
0.52ft
1.05ft
1.57ft
2.10ft
2.62ft
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3.15ft
4.20ft
5.25ft
6.29ft
7.34ft
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10.49ft
12.59ft
14.69ft
Proc
< Step
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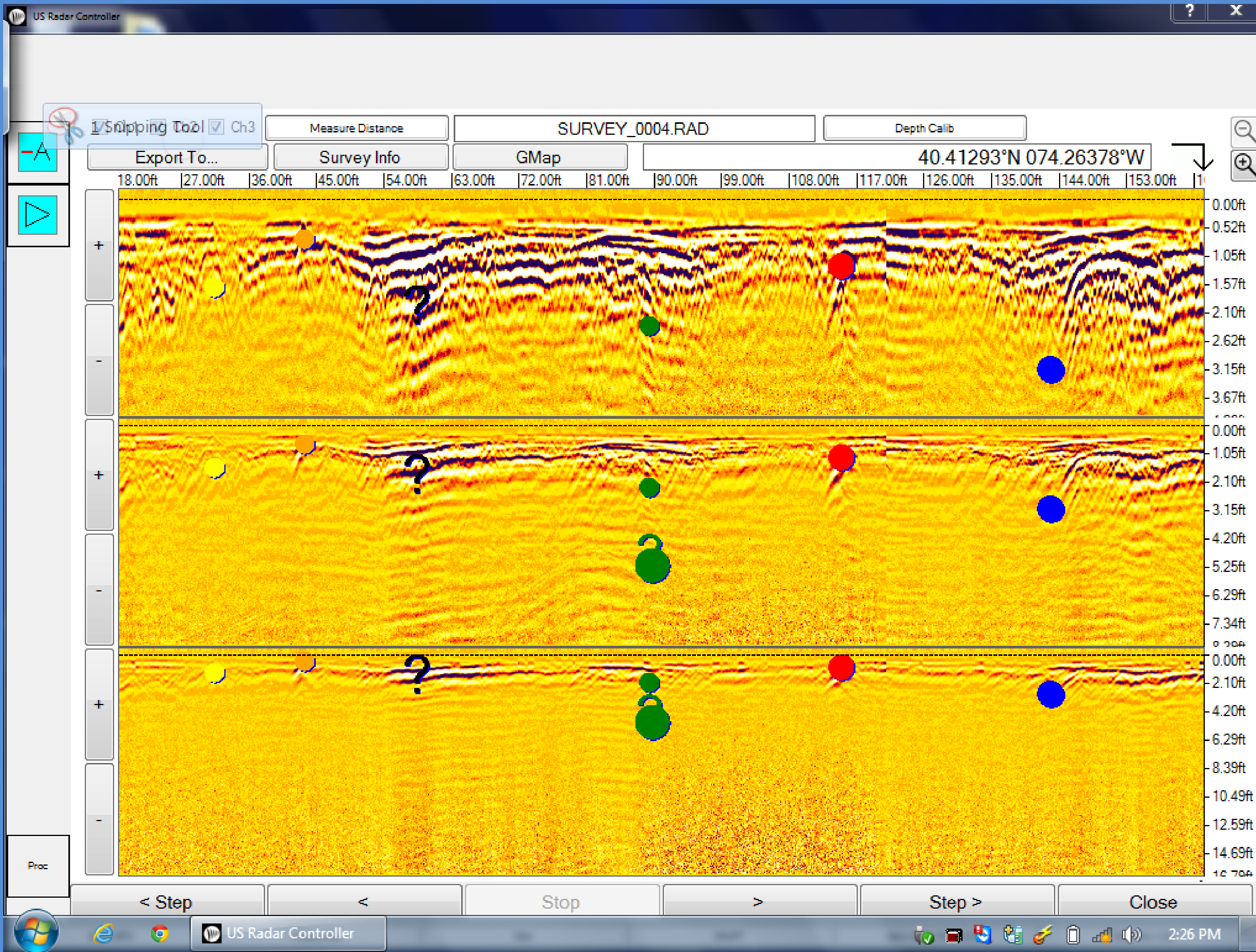
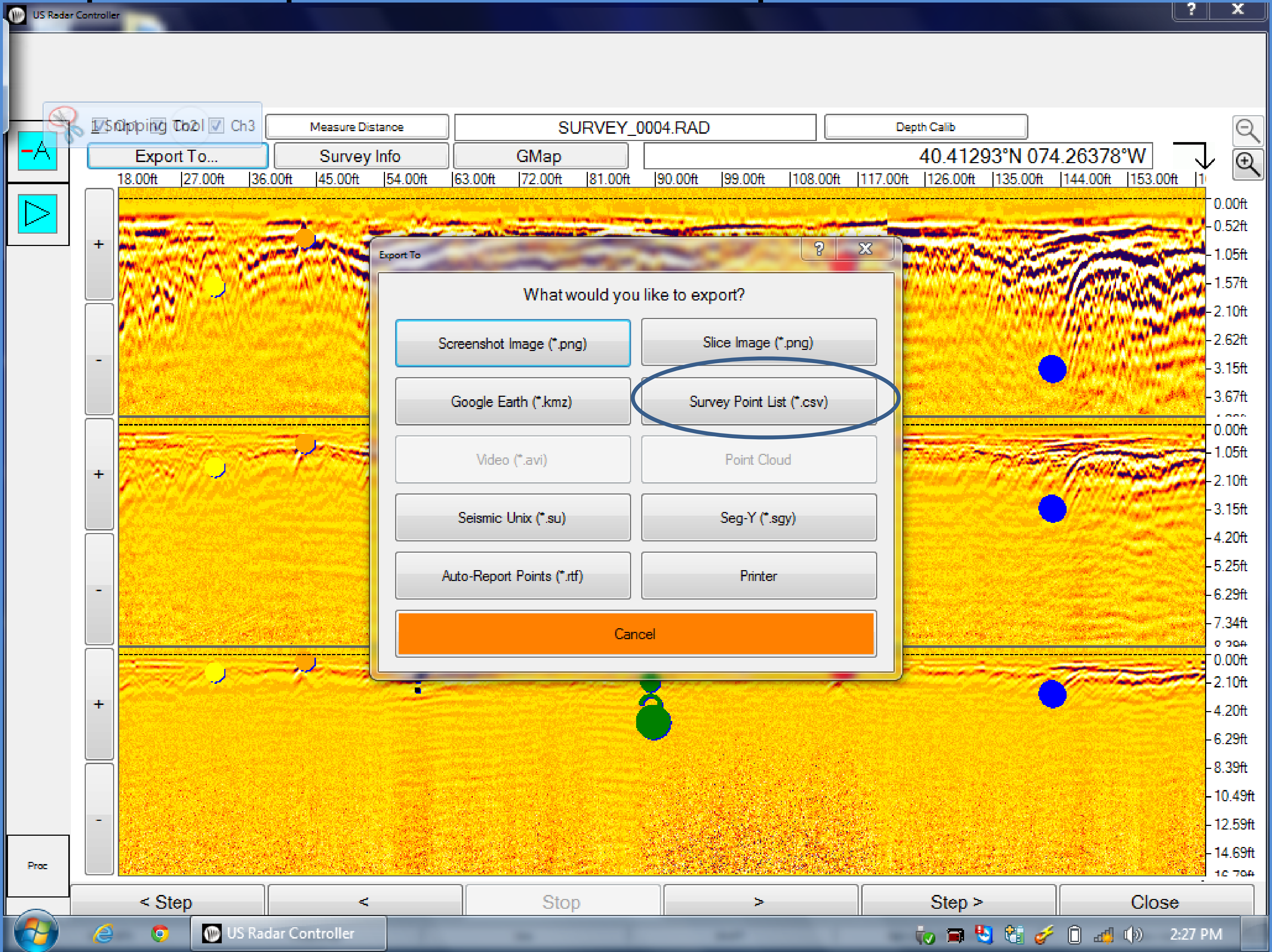
Step >
Close
US Radar Controller
2:23 PM

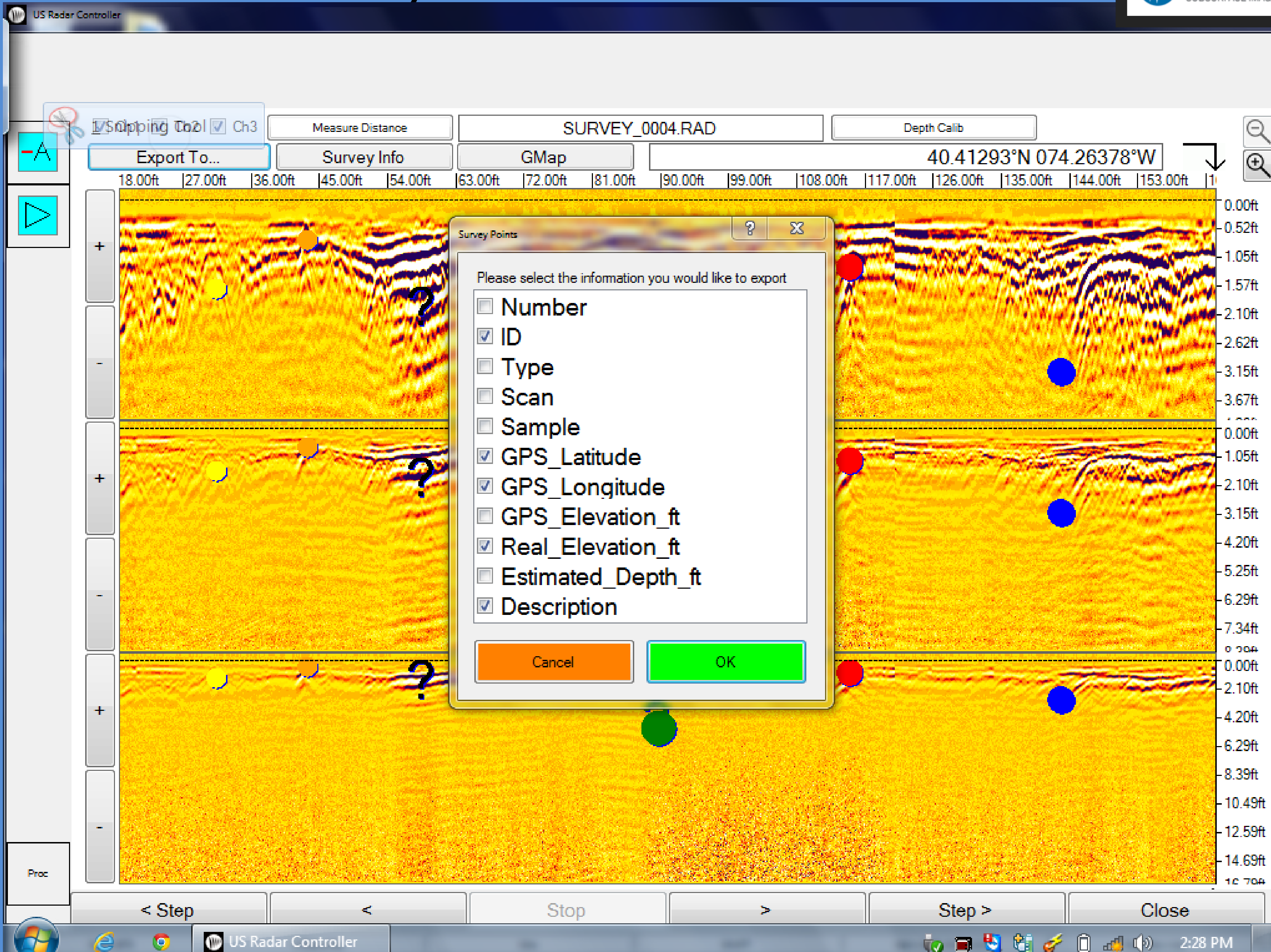
Now tag all of your points, in the field and/or in the office



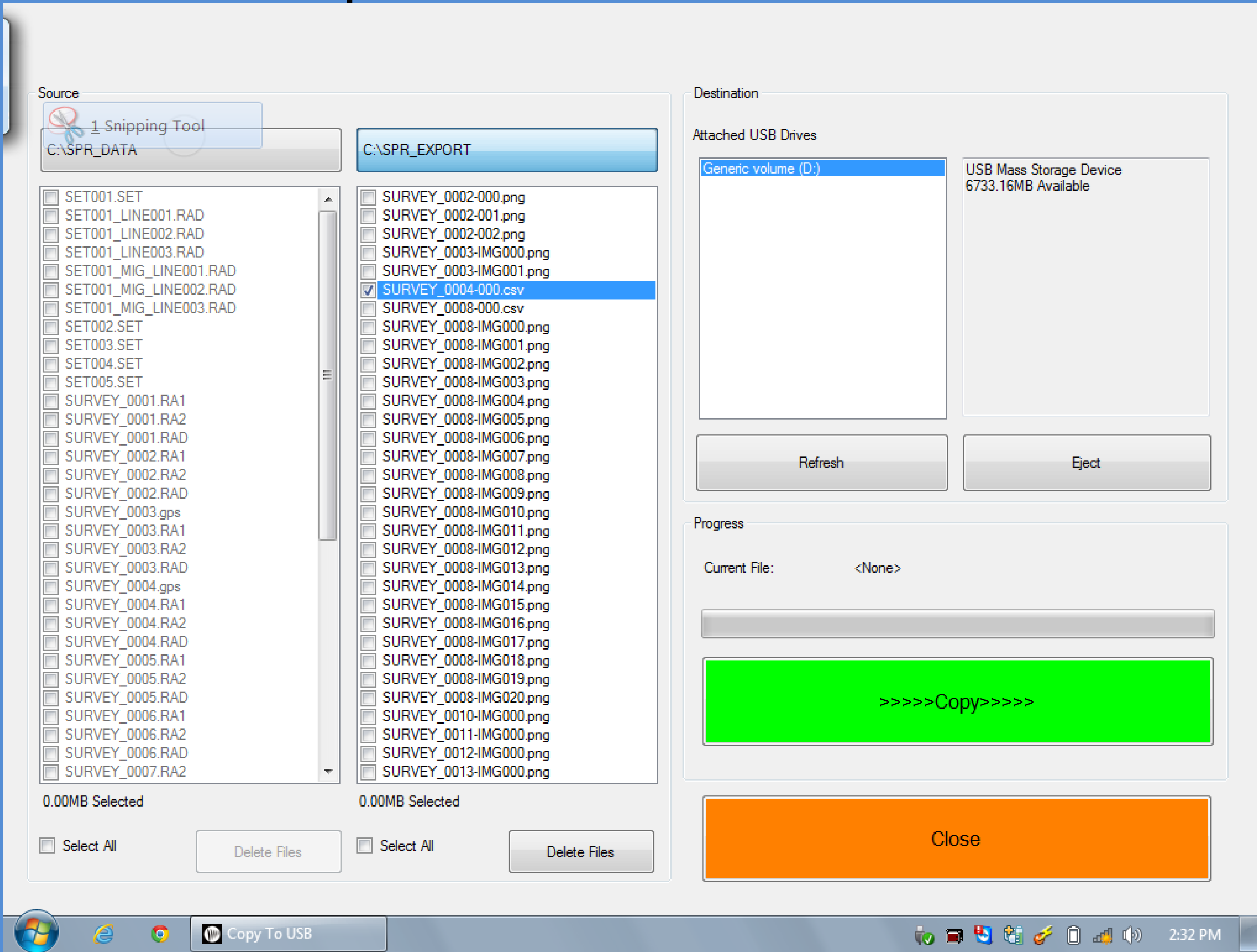
Export the point file or choose point cloud if 3-d

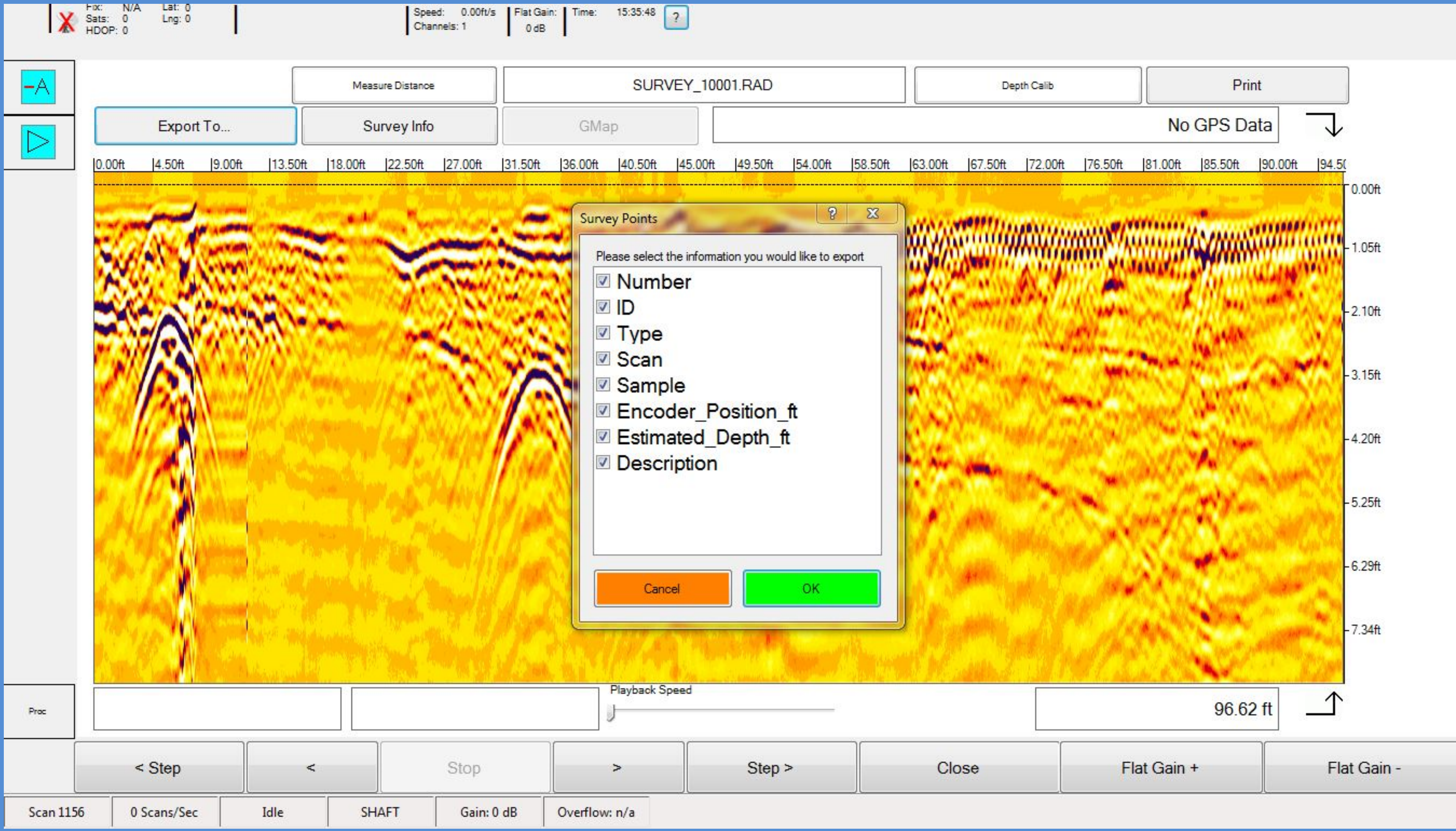


Pick the data you want to transfer

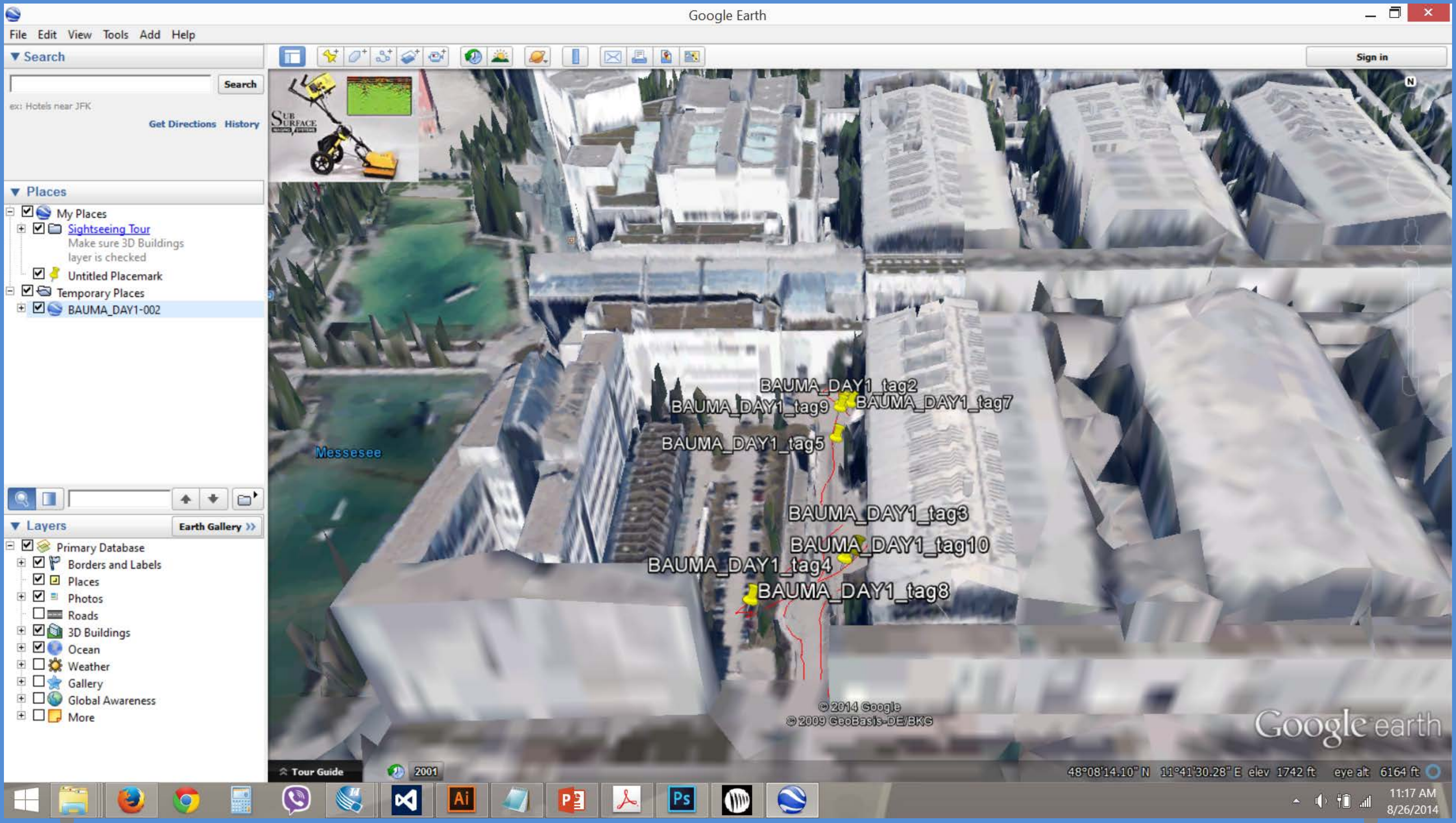


Files are copied and transferred via usb

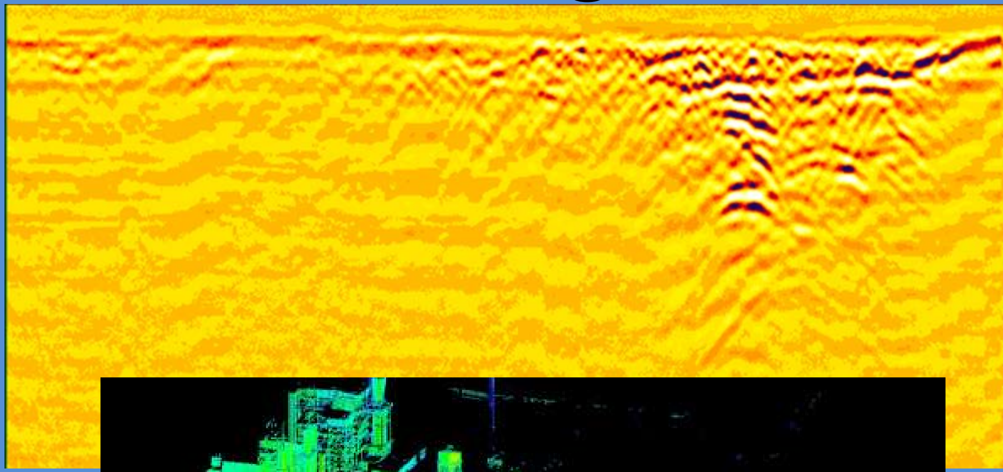


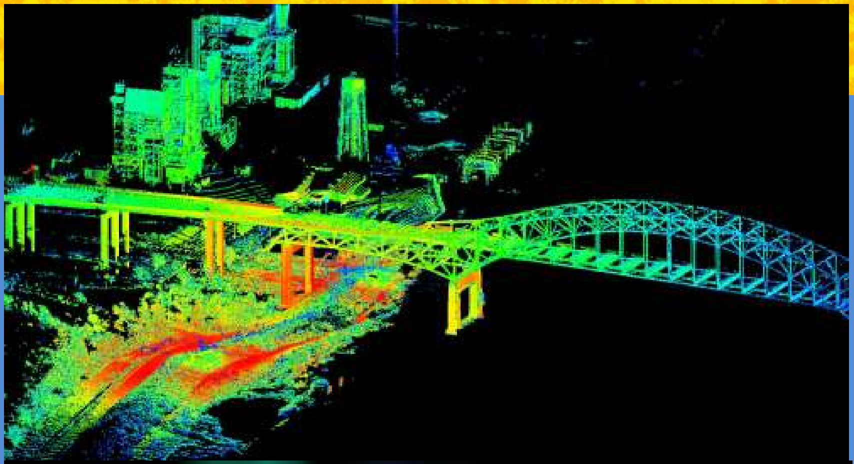

Fix: N/A
Sats: 0
HDOP: 0
Lat: 0
Lng: 0
Speed: 0.00ft/s
Channels: 1
Flat Gain: 0 dB
Time: 15:35:48
?
Measure Distance
SURVEY_10001.RAD
Depth Calib
Print
Export To...
Survey Info
GMap
No GPS Data
0.00ft
4.50ft
9.00ft
13.50ft
18.00ft
22.50ft
27.00ft
31.50ft
36.00ft
40.50ft
45.00ft
49.50ft
54.00ft
58.50ft
63.00ft
67.50ft
72.00ft
76.50ft
81.00ft
85.50ft
90.00ft
0.00ft
1.05ft
2.10ft
3.15ft
4.20ft
5.25ft
6.29ft
7.34ft
Survey Points
Please select the information you would like to export
Number
ID
Type
Scan
Sample
Encoder_Position_ft
Estimated_Depth_ft
Description
Cancel
OK
Proc
Playback Speed
96.62 ft
< Step
<
Stop
>
Step >
Close
Flat Gain +
Flat Gain -
Scan 1156
0 Scans/Sec
Idle
SHAFT
Gain: 0 dB
Overflow: n/a

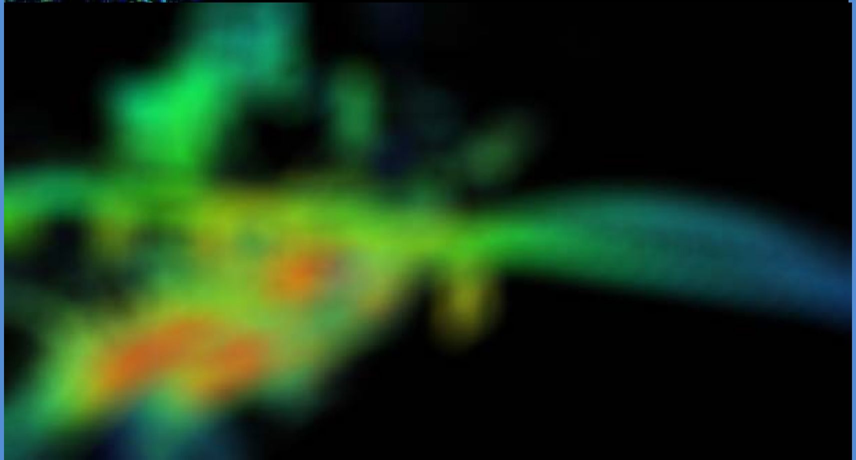
Or Google Earth…



There are some challenges



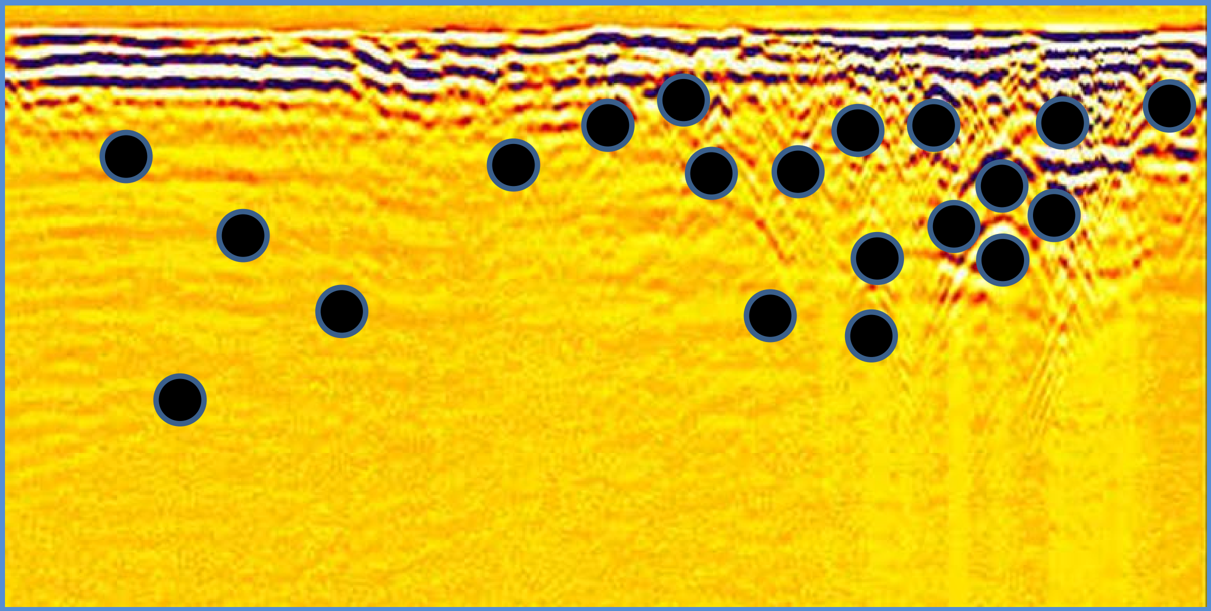




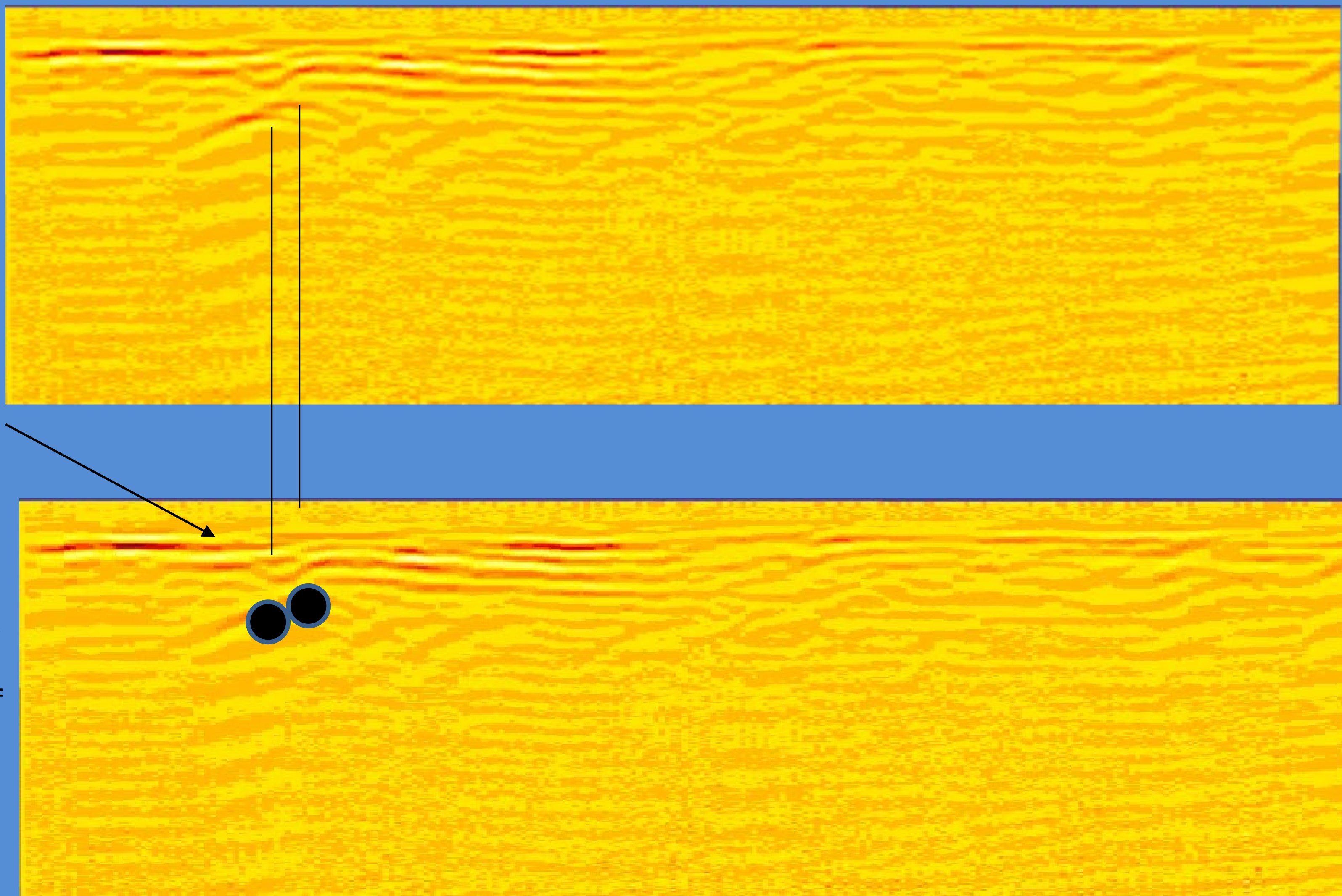
·GPR data is raster/bitmap data as opposed to the vector data that
is in Autocad drawings.
·So, it's closer to laser scanner data than it is to an autocad drawing.
·However, we have to use much lower frequencies to penetrate into
the Earth than those a laser scanner uses to penetrate air, therefore
the data is much lower resolution than a laser scanner. This will
continue to be the case unless physics has a law repealed or a new
one passed. Very simply, low frequency = penetration,
high frequency = detail
·By comparison think of it as almost a laser scanner that needs
glasses, but isn't wearing them, so typical pointcloud workflows
don't usually work so great.
·While the blurry image doesn't give much detail about the bridge,
it is still possible to determine that a bridge is there, especially with some
background info and context clues about the site.
·Let's keep in mind that:
1) Pipes are a lot less intricate than bridges.
2) The blurry image of the bridge and buildings is a lot more useful than
having no image at all. .

Automatic conversion is the holy grail.

Many attempts have been made towards an automatic conversion by gpr manufacturers and academia, and there has yet to be any significant success The problem becomes that no matter how extensive and elaborate the recognition algorithms are, the tendency to call every hiccup in the data a pipe makes this task extremely challenging.

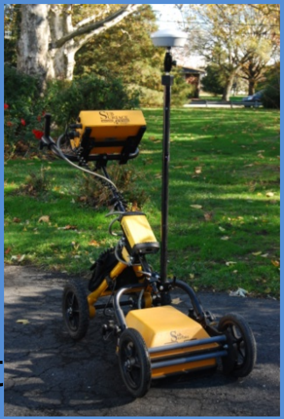


Some algorithms have the inverse problem and miss faint targets that are obvious to a human being with background information about the site. In this case, the algorithm did not detect any targets giving us a false negative-not a good thing if we are going to be digging here. But what if a human being examined this image knowing that as-builts indicate the presence of two small diameter plastic pipes?



“U” shaped break in surface layers indicates trenching activity took place, clueing us in to the location of these fainter more elusive utilities.

So for now…



1) Treat the gpr like a data collector using a gps unit and manually select points on the cross-section data in real time in the field. Export these points to some sort of survey/civil software and connect just as we would with normal land survey data

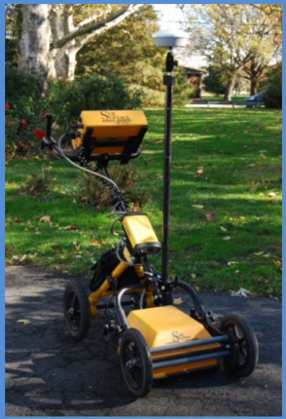
OR

2) Make marks on the ground in the field, and capture these points with a survey instrument, optionally adding the depth of the target to the rod height in the data collector to get true z coordinates (integrate with existing survey/gis workflows). Since this method is self-explanatory, it will not be discussed further.

OR

3) Export plan view slices and/or peakmap to autocad, trace over these in autocad. Note: that this approach will work better on some sites than others.

…and you're going to need a source of 3d positioning data-generally GPS



But remember, handheld GPS is very inaccurate and as accuracies increase, so do prices

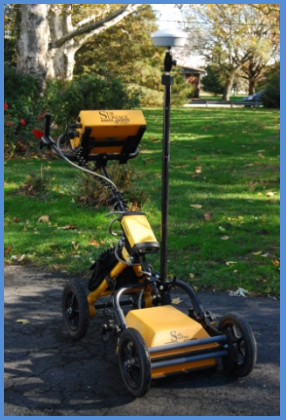
Single Frequency GPS:
Uncorrected GPS (cellphone): ± 9 Meters (30 ft.) - practically free
WAAS/EGNOS (handheld GPS): ± 1-3 meters (10 ft.) - $100
Beacon (Older GIS GPS backpack): ± 1 meter (3 feet) - $5000
Omnistar augmented GIS: submeter to meter (4” or higher) - $5000 + $1500/yr subscription – may require up to 45 min of initialization before collecting data
Post Processing of GIS GPS: ± decimeter to submeter (~4”) - $6000 not with GPR-must be real time

Dual Frequency GPS:
RTK with VRS reference network: ± 1 cm+ (1”+) - $20,000 + cell data plan + reference network subscription $varies
RTK with local base station: ± 1 cm(1”) $40,000

Non-GPS sources of positioning:

Manual Total Station: ±5 mm(depending on many factors) - $5000-$10000 – doesn't integrate with gpr well
Robotic Total Station: ±5 mm(depending on many factors) - $30000 – not ideal but can integrate with gpr
On site reference points (lay out a grid): generally relative 2d positioning, do not factor in elevation changes, depths are relative to surface elevation - $free (sometimes possible for a surveyor or GIS technician to translate local coordinates to a world coordinate system (lat/long, state plane, UTM, etc.)

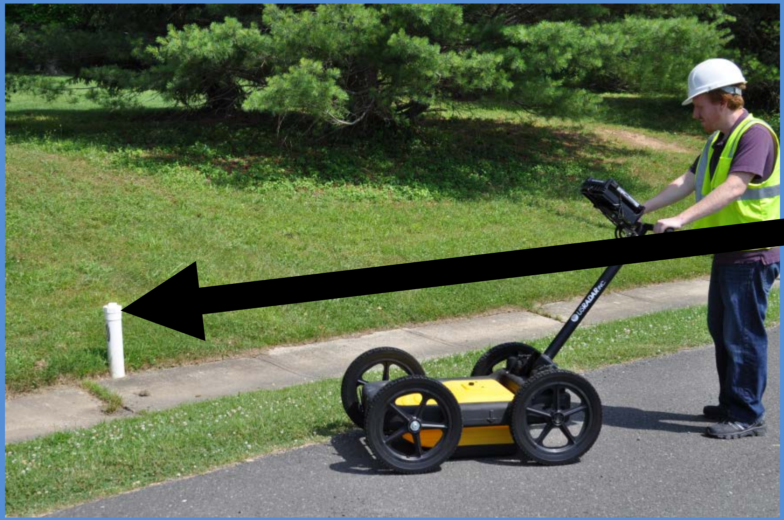
Approach #1 – Treat the Radar like a data collector
Mapping Applications

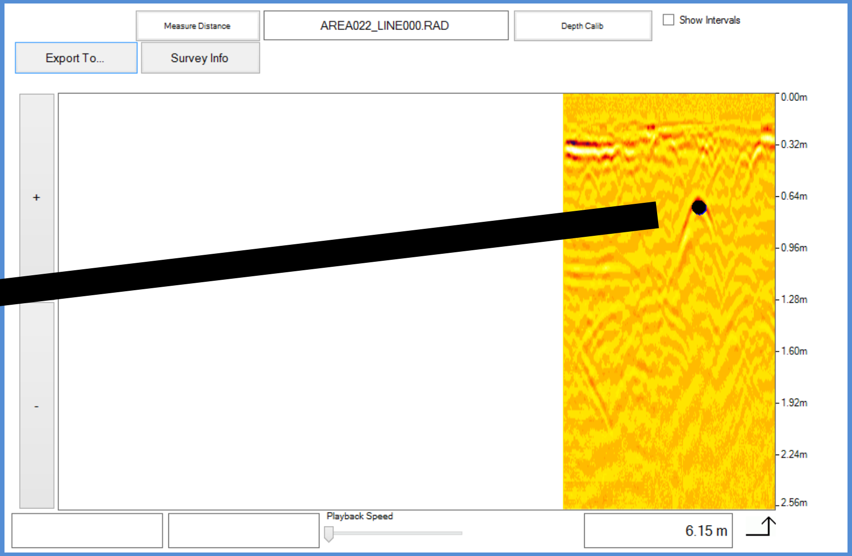


Treat the gpr like a data collector using a gps unit and manually select points on the cross-section data in real time in the field.
1) US Radar GPS Annotation module
Export these points to some sort of survey/civil software and connect the dots, just as we would with normal
land survey data.

Advantage: When we analyze data in the field, we get to take advantage of visual context clues that might not be documented when analyzing data back in the office.

If we had to analyze the cross section on the right in the office,we could determine that we have a potential pipe, but with field information, we can confirm we have a pvc sewer lateral.





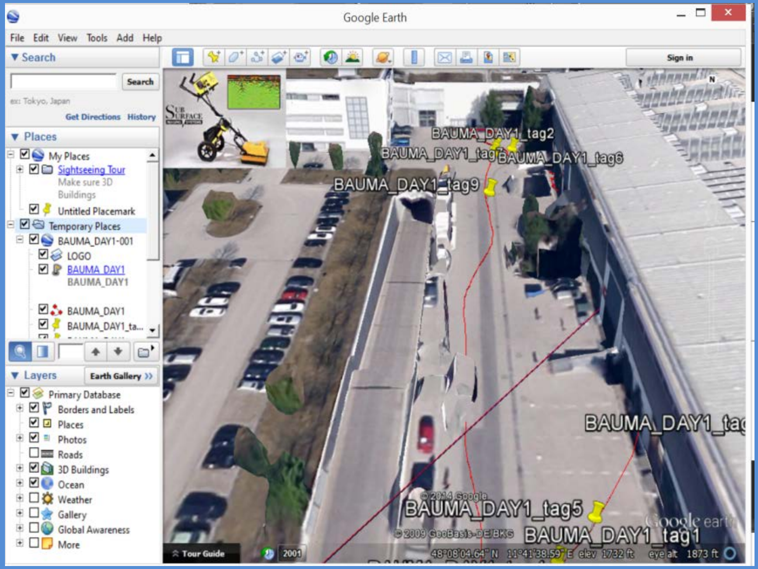
Approach #1 – Treat the Radar like a data collector Mapping Applications

2) US Radar Google Earth Module

Capabilities:

a) .kmz internet connection required on site

b) view Google Earth satellite and as-builts (if available) in split screen & real time while collecting radar data (requires internet connection)



Approach #1 – Treat the Radar like a data collector

Mapping Applications

3) Carlson GIS360

Capabilities:

a) Native Google Earth survey data collection & basic connect the dots drafting

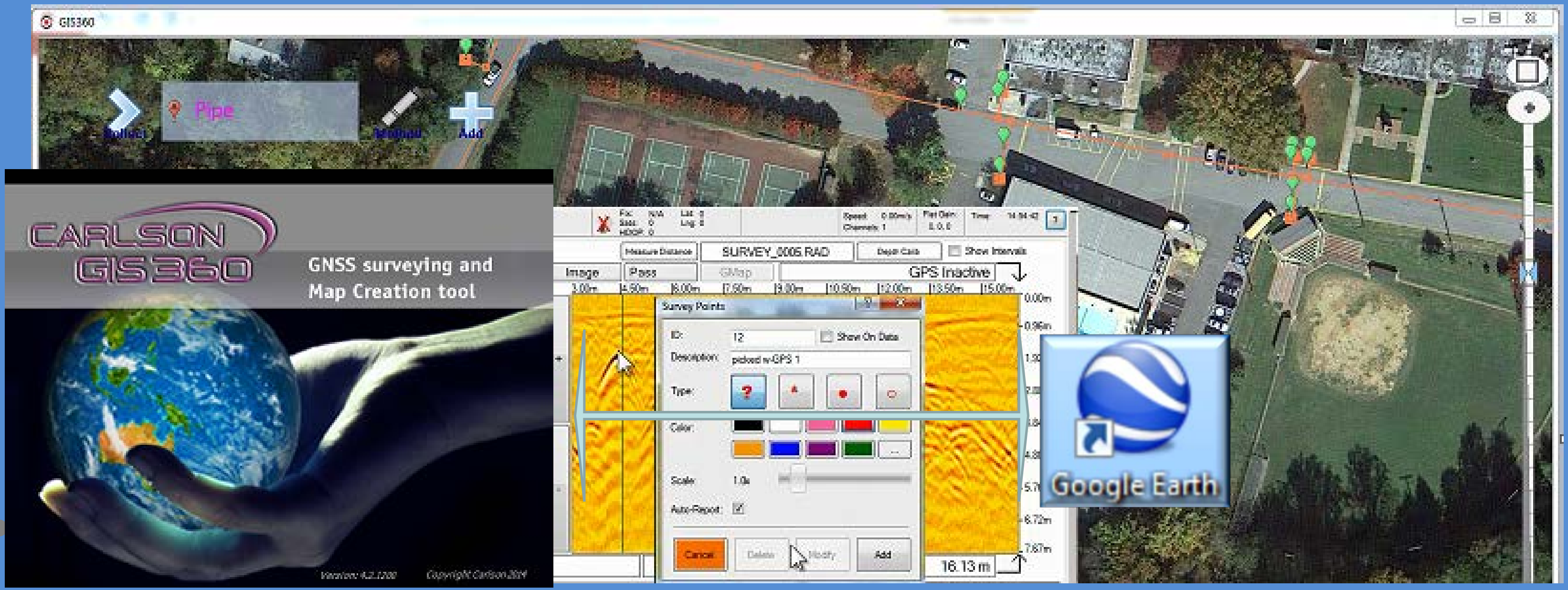
b) Split screen view as-builts and collected vector survey data while collecting radar data

c) Collect points and annotate lines and features while recording radar data

d) Caches Google Earth tiles (no internet Connection required for satellite or map data)

e) Uploads and downloads work from the cloud-great for coordinating amongst many crews (requires internet connection)

f) .kmz deliverables



Approach #1 – Treat the Radar like a data collector

Mapping Applications (continued)

4) Carlson SurvPC-Advanced Land Survey Grade Data Collection

Capabilities:

a) Runs in split screen on radar control pc for data collection

b) View .dxf as-builts on split screen in real-time

c) Select point on radar data, point , depth, & description information gets automatically sent to Survpc

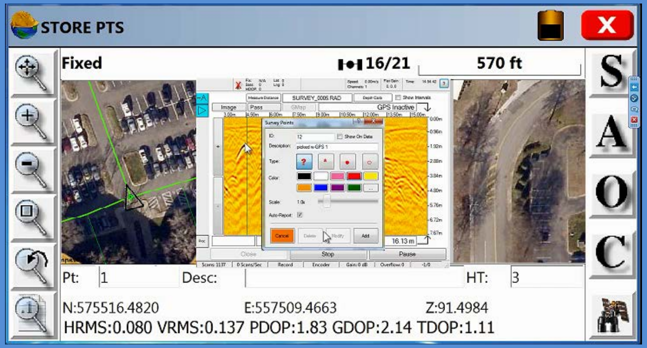
d) Native Autocad .dxf or Esri data collection

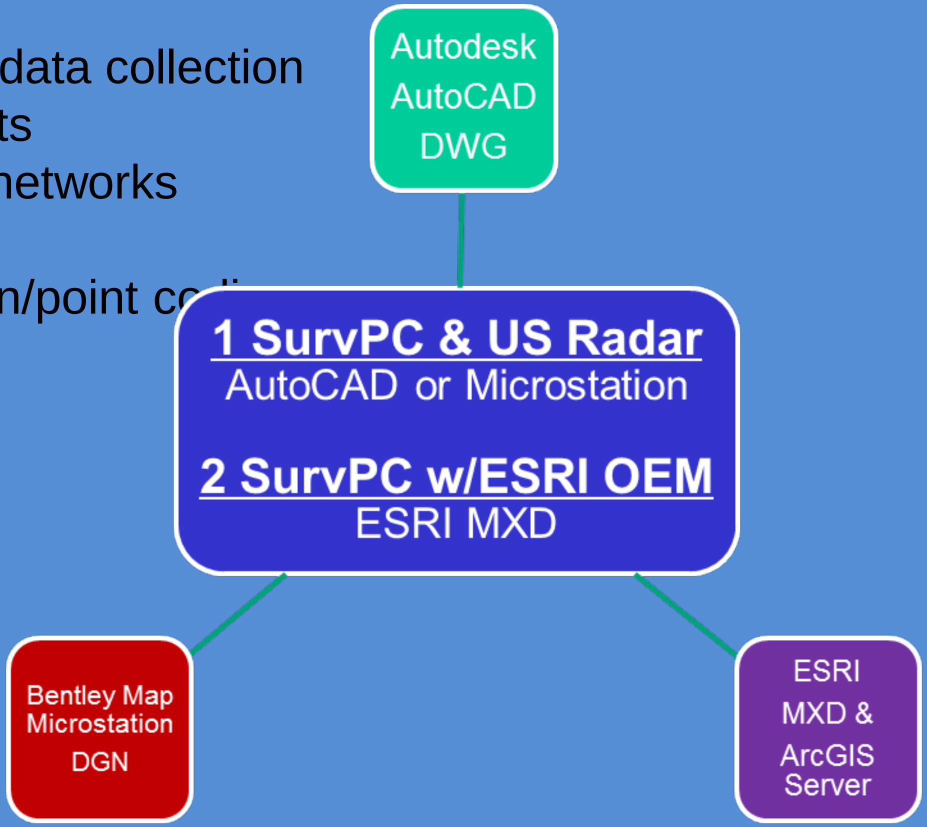
e) Drivers for many instruments

f) Support for GPS reference networks

g) Support for total stations

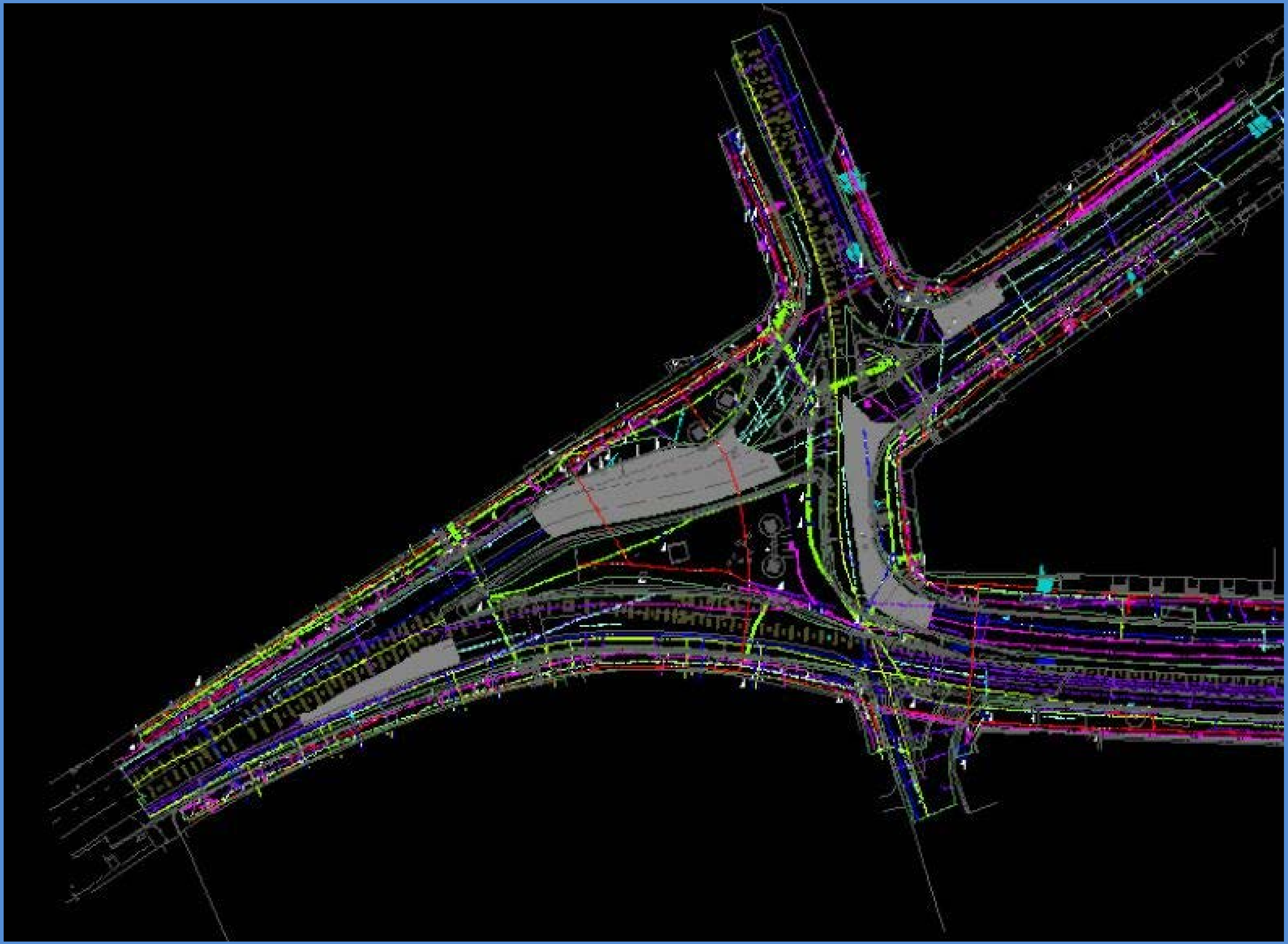
h) Field to finish data collection/point co



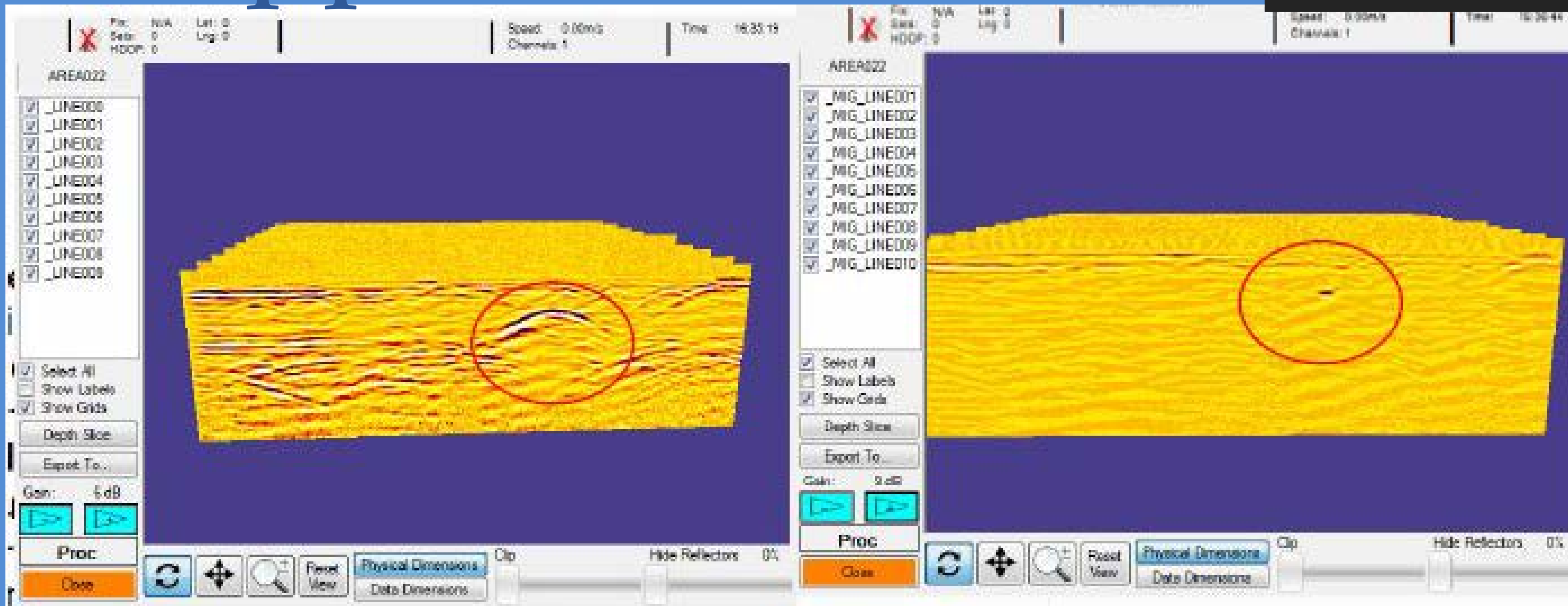


Approach #1-Treat the radar like a data collector.

End result when combined with land survey information



Approach #3-3D Da



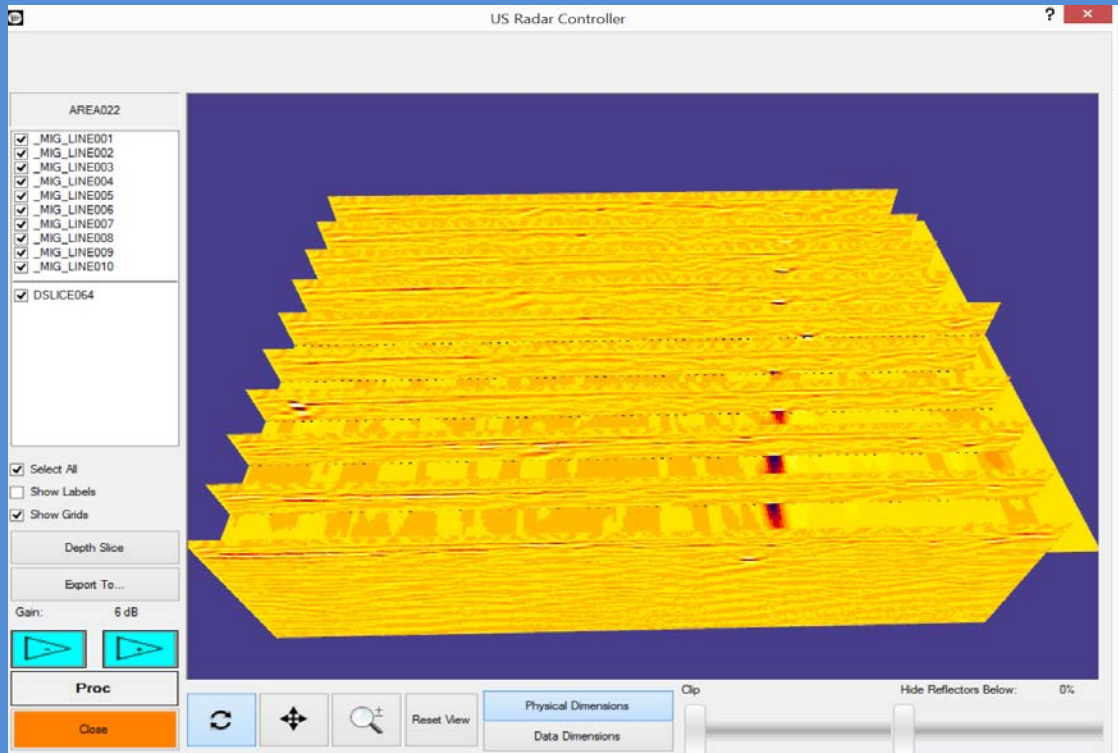
Cross section data must be filtered and hyperbolas corrected to generate 3d bitmap data.
Two notes:

1) Generally it is only possible to post-process data subtractively (background can be removed, but things which do not appear cannot be added). No CSI-style image enhancements in the real world.

2) Look at the raw cross section on the left and the corrected/processed cross section on the right. In which image is the pipe more obvious and noticeable?

Now you know why real-time data is not highly processed.
The chance of a false negative result is too high.

Approach #3-3D Data

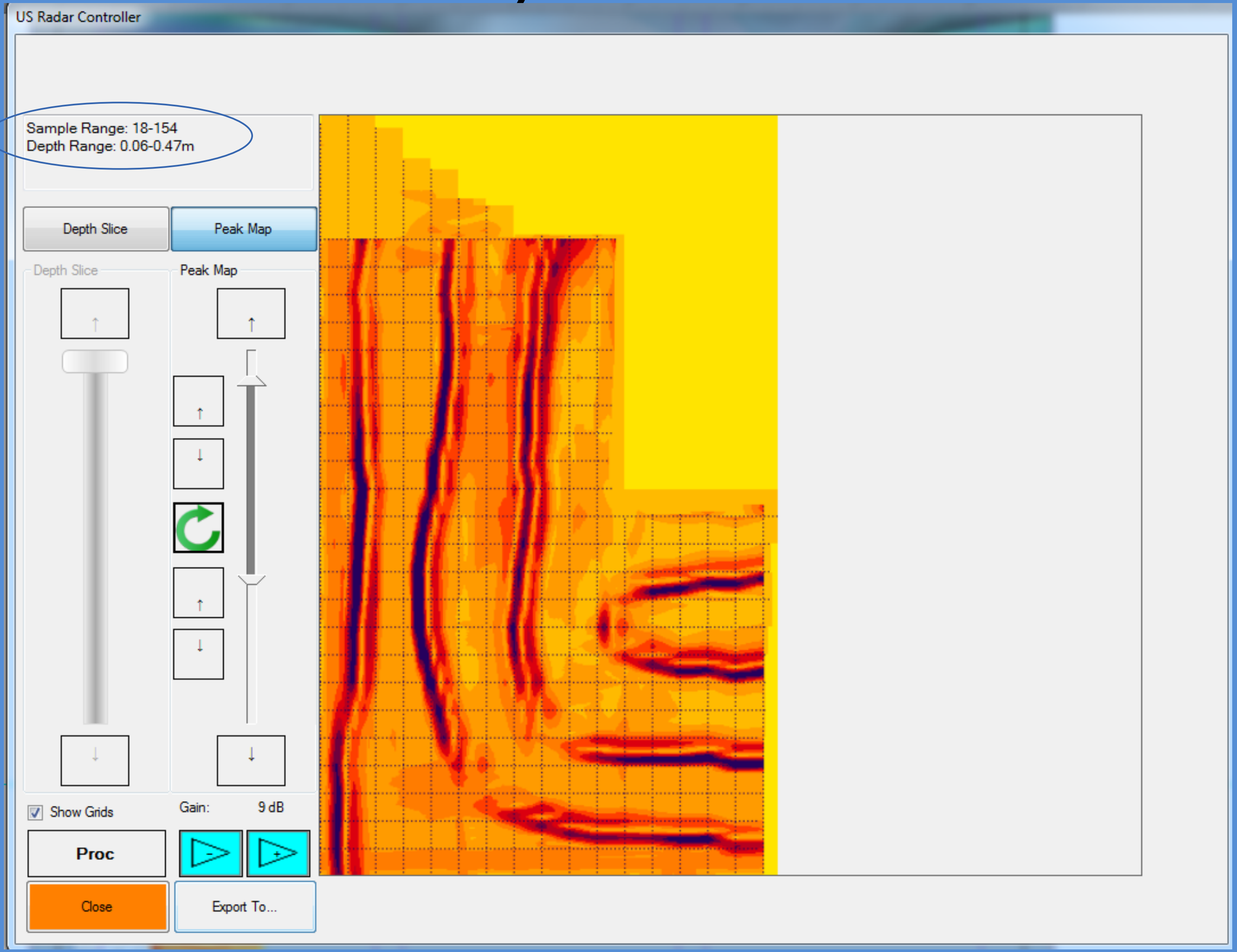


After cross-sections are processed, then an interpolation algorithm connects/stitches the 'blips' from one cross section to the next.

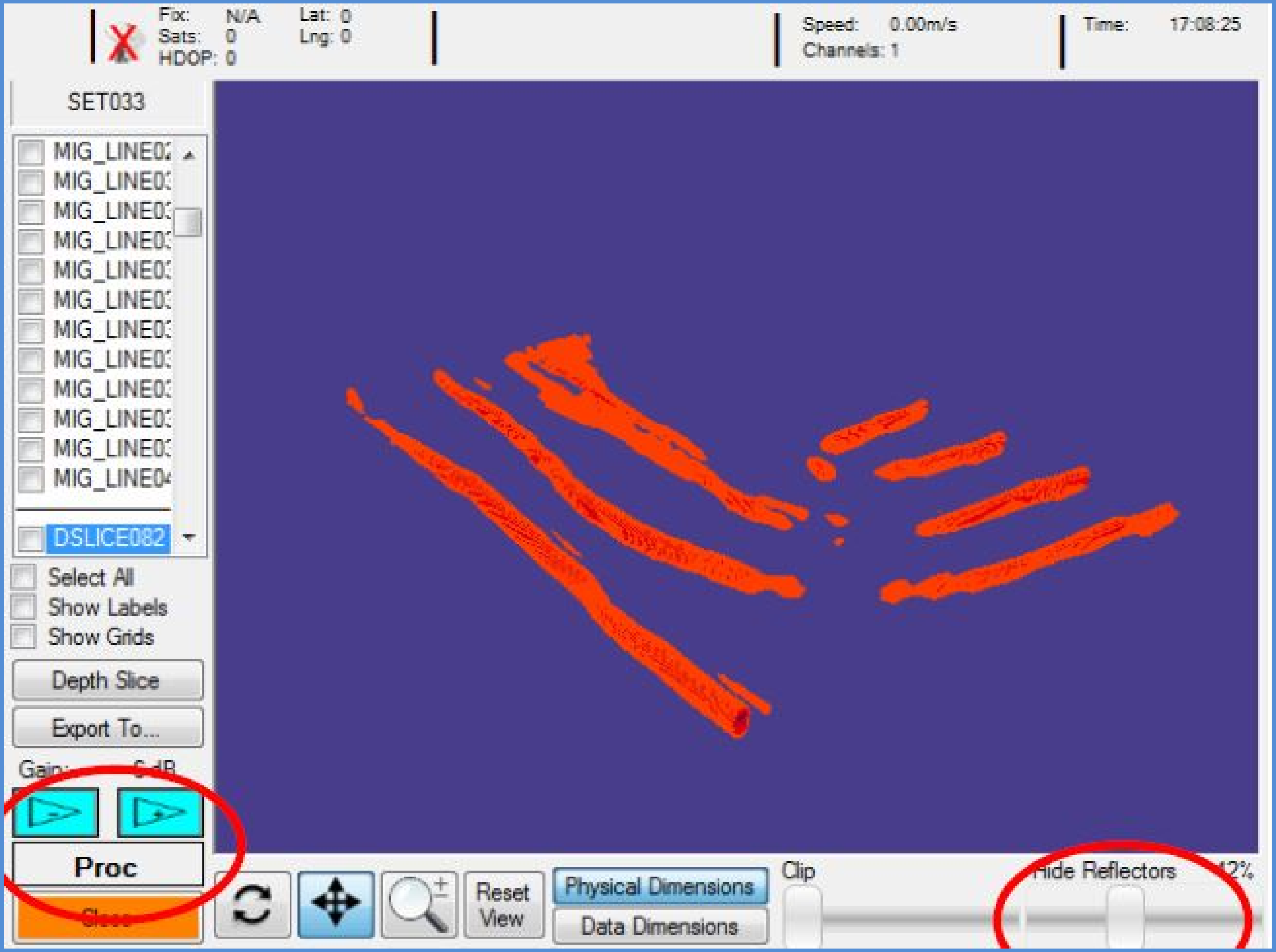
As with any automatic algorithm, interpolation can sometimes fail to connect the right dots too each other. It can either be too lax and connect things that shouldn't be connected or it can fail to connect things that should be connected (faint targets). Therefore, interpolation works best with minimal clutter and nice, clear data.

Approach #3-3D Data

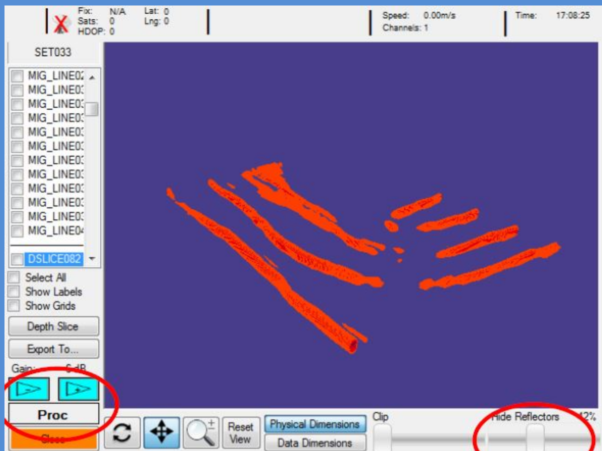
Peak Map-(3D Radar survey bitmap deliverable)

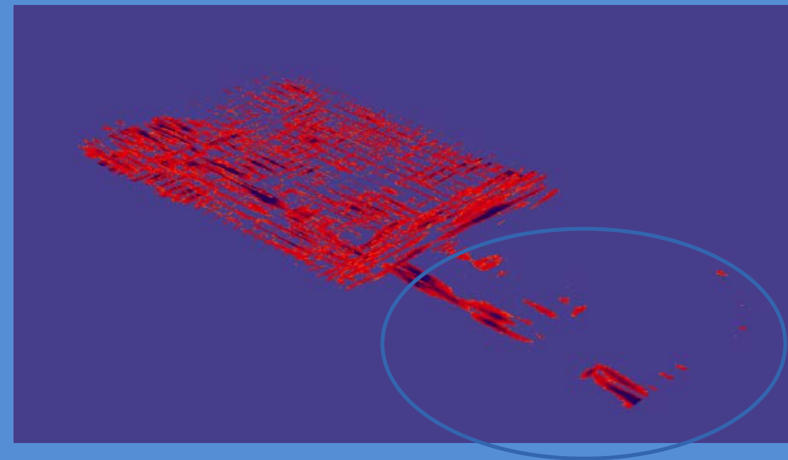


Approach #3-3D Data



Real World 3D Data





The quality of the results can vary from site to site-it's not always like in the brochure. It's useful information, but generally will not lead directly to BIM compliant deliverables without some degree of human interaction.

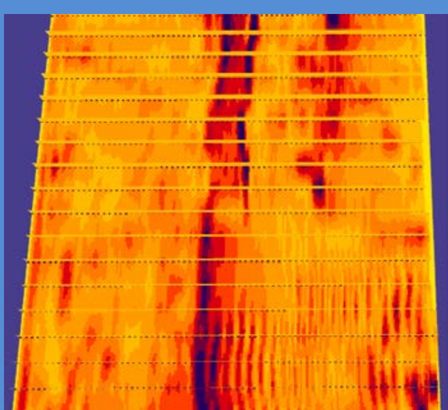
Here are real world examples of good, medium, and poor data.

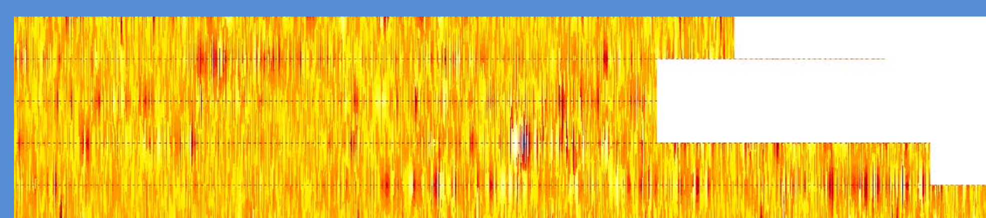
Top left: radiant heat loops in floor.

Top right: two pipes under rebar, note the gap where the interpolation algorithm didn't connect the dots

Bottom left: ? Actually it's 3 parallel pipes, however, some condition at the site or a problem in processing has caused the lower right hand corner of the data to be useless and the upper right hand corner is very faint.

Bottom Right: ? Actually this sample as well as the one to the left of it were both send in to technical support and it turned out that in addition to tough conditions existing on site, there were also some flaws in the customers’ collection methodology.





Great we have 3D data-Now what?

Option 1) Export point cloud into a point cloud software. Note that the laser scanner point cloud softwares do not handle geophysical point clouds as well as laser scanner clouds...yet.
In a laser scanner point cloud, there are no rocks or geophysical features and unlike soil is to the radar, air is invisible to the laser scanner. In order to make the geophysical point cloud behave like an aboveground point cloud, it must be heavily filtered. When heavily filtered, fainter hits such as small plastic pipes will tend to be removed along with the background soil.

There are some geophysical point cloud softwares, but these are specialized programs and are good at visualization, but not at producing vector cad drawings.

Great we have 3D data-Now what?

Option 2) Vectorize the 3D data.

Manual or automatic?

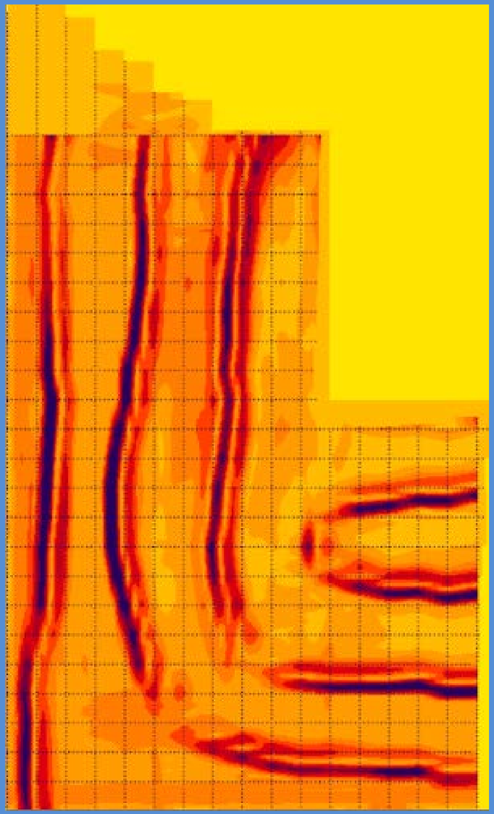
Just like with cross sections, automatic interpretation is the holy grail, but very little progress has actually been made in industry or academia. There have been some claims made to the contrary, but the results just don't live up to the claims.

No long-established GPR hardware & software manufacturer claims to be able to automatically interpret 2d or 3d data.

Some software startups which use others hardware and in some cases are either seeking venture capital/investors or are providing locating services (with very well-written contracts) claim to be able to do what a 40+ year old industry run by Phd electrical engineers and geophysicists does not claim is currently feasible. Buyer beware.

The proof is in the results.

3D Data-interpretation-a good dataset



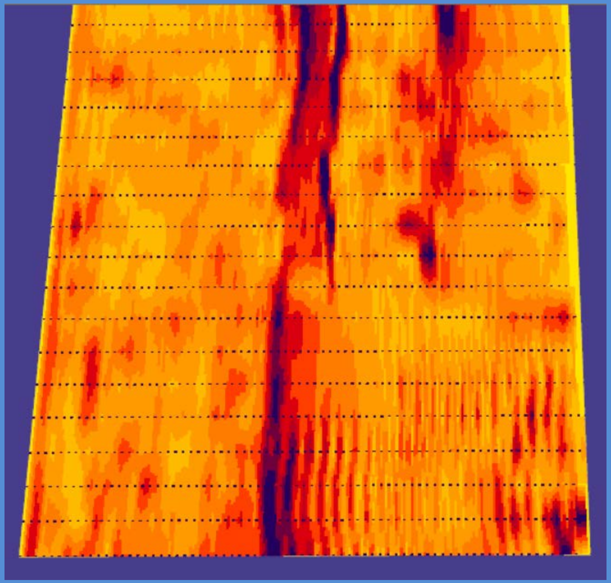
Left: original data

Middle: Computer Generated

Right: Human Traced Data

Note: Computer-based algorithms are better at finding edges than centerlines.

3D Interpretation-a poor dataset



Left: original data

Middle: Computer Generated

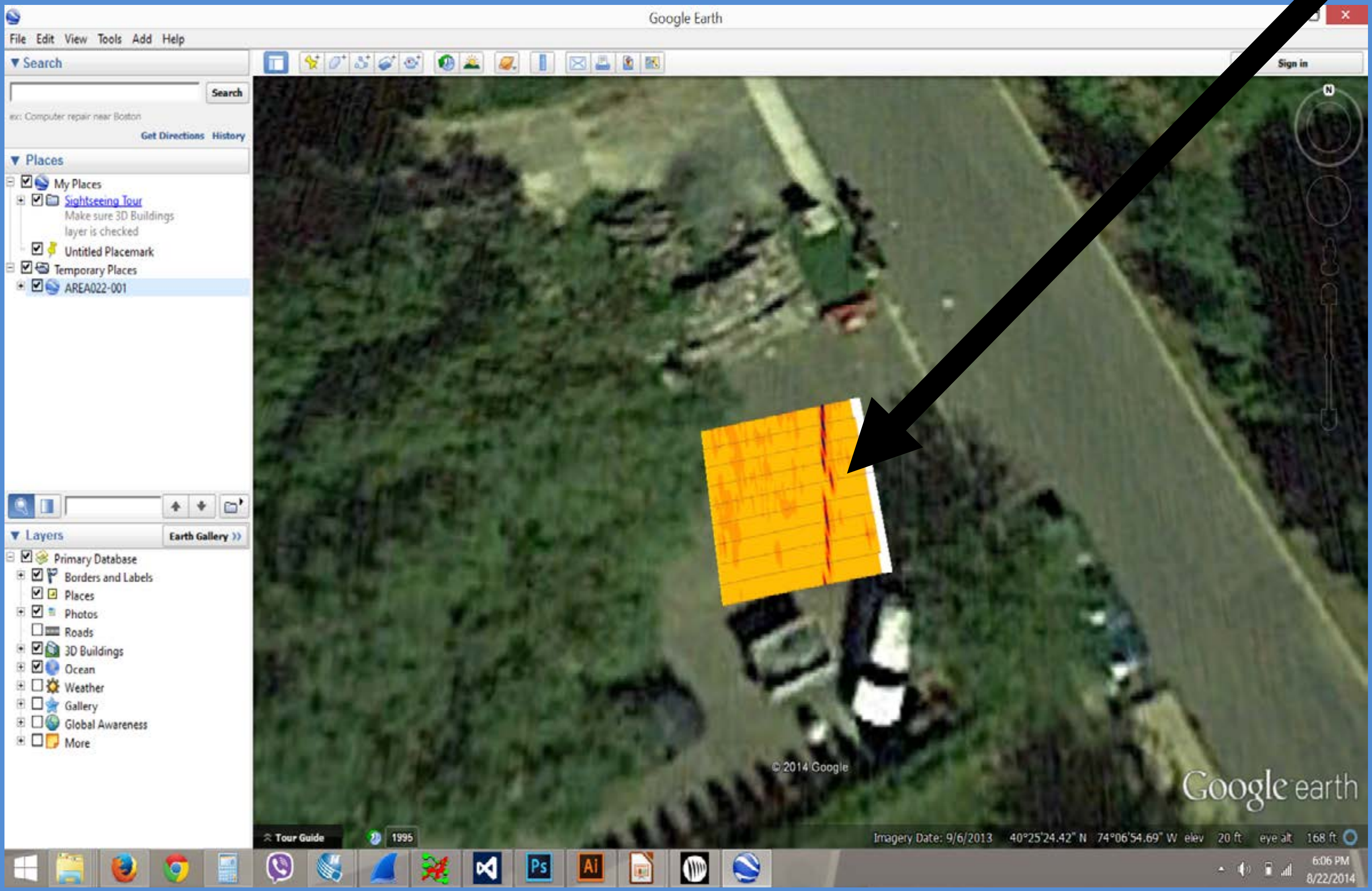
Right: Human Traced Data (took 2 minutes)

Note: Computer-based algorithms are better at finding edges than centerlines.
Note 2: The human reviewed the as-built which indicated 3 pipes.
The human realized something is missing in the lower right hand corner and extrapolated the pipes.

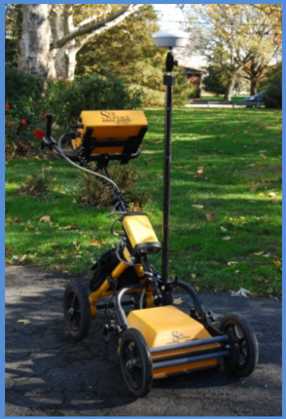
Great we have 3D data-Now what?

Option 3) Export a georeferenced image of the data to Google Earth or ArcGIS

GPS error



In summary, if you want to make maps from GPR Data, you need a GPS and you'll want to take one of the approaches we reviewed.



1) Treat the gpr like a data collector using a gps unit and manually select points on the cross-section data in real time in the field. Export these points to some sort of survey/civil software and connect the dots, just as we would with normal land survey data.

OR

2) Make marks on the ground in the field, and capture these points with a survey instrument, optionally adding the depth of the target to the rod height in the data collector to get true z coordinates (integrate with existing survey/gis workflows). Since this method is self-explanatory, it will not be discussed further.

OR

3) Export plan view slices and/or peakmap to autocad, trace over these in autocad. Note: that this approach will work better on some sites than others.

We're working on it full time

And we are making progress

But it will only come together with the help and support of the community.

We need your continued input   We need your continued guidance

We need you to continue to put our technology to use in the field.

Thank You

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