



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

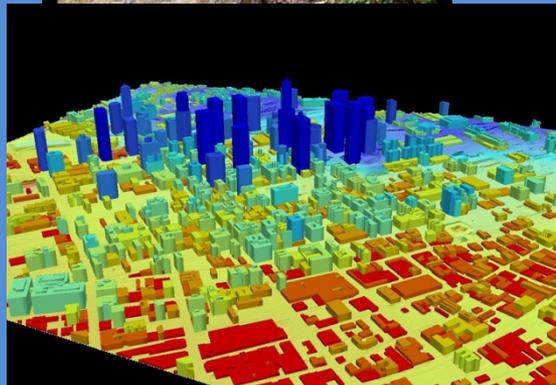
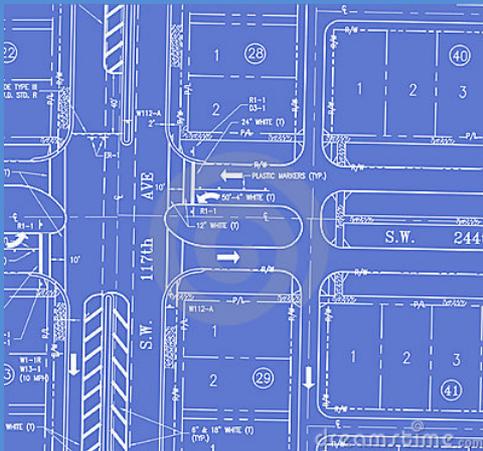
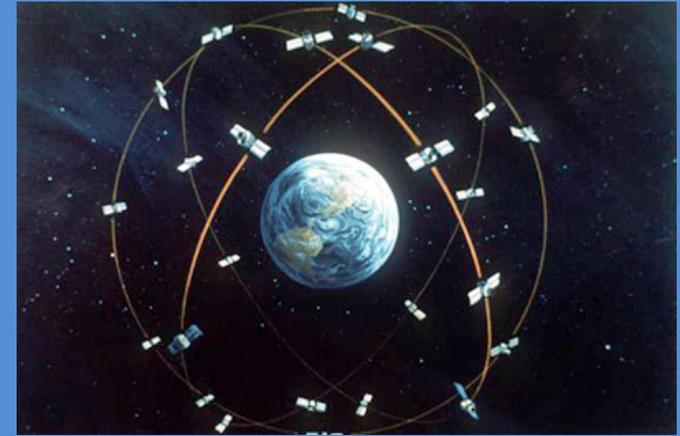
(and mapping what we find)
Taking it to the next level

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

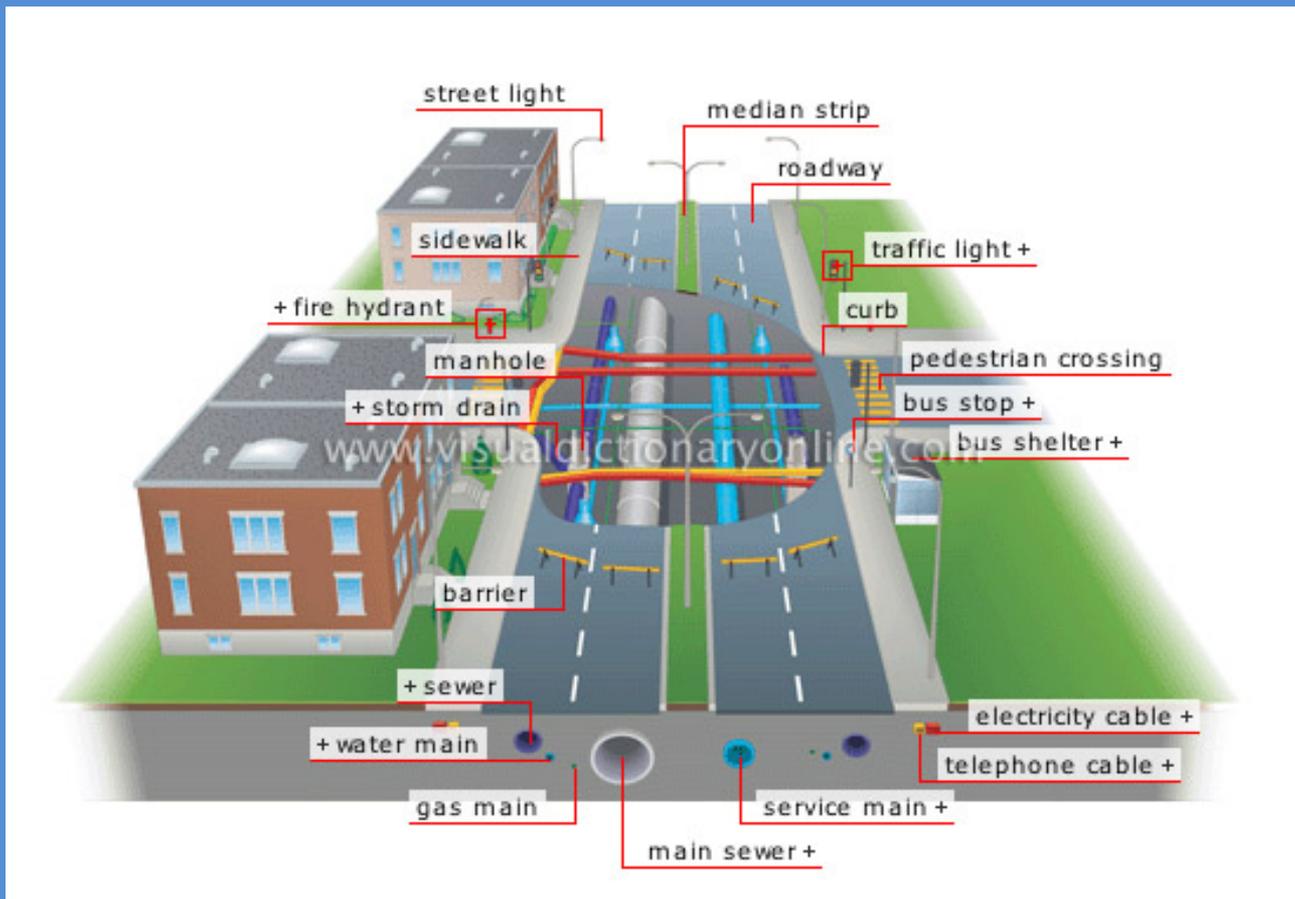


So now we're figuring out how to map what some surveyors and engineers have called... "the final frontier"



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, today's 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

Types of Pipe

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

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

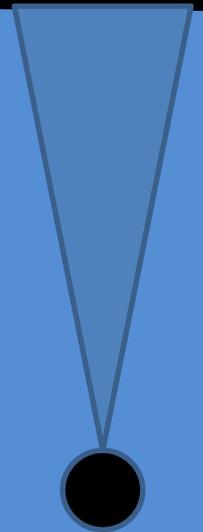
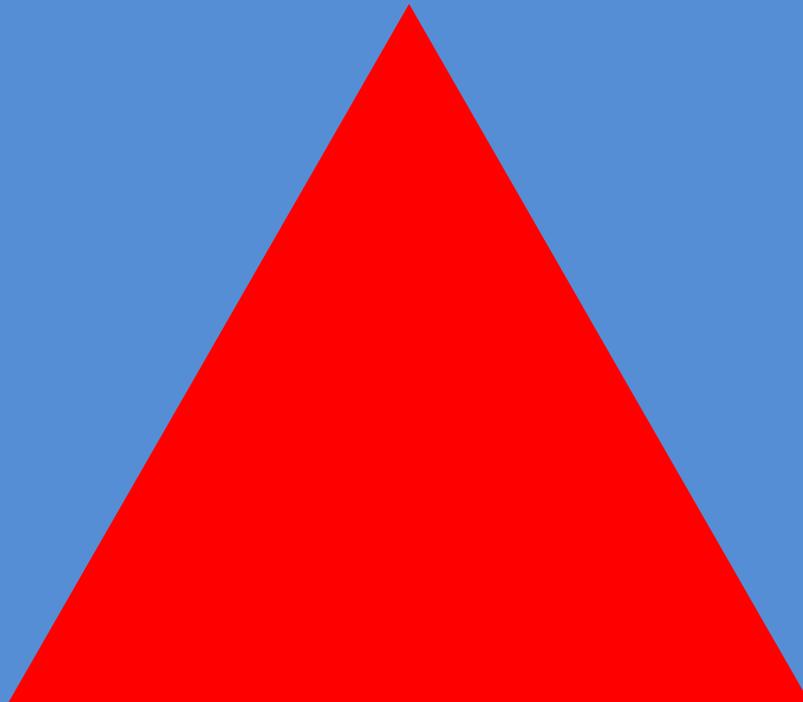
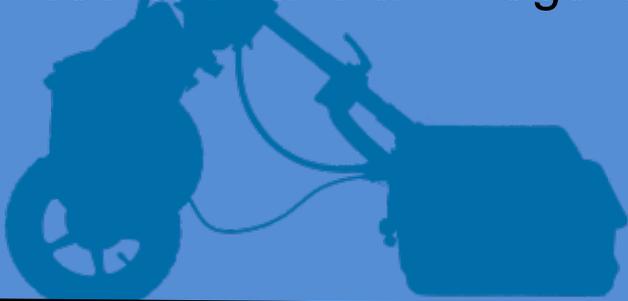


A raincloud is completely different from the surrounding blue sky and will show up as an anomaly.



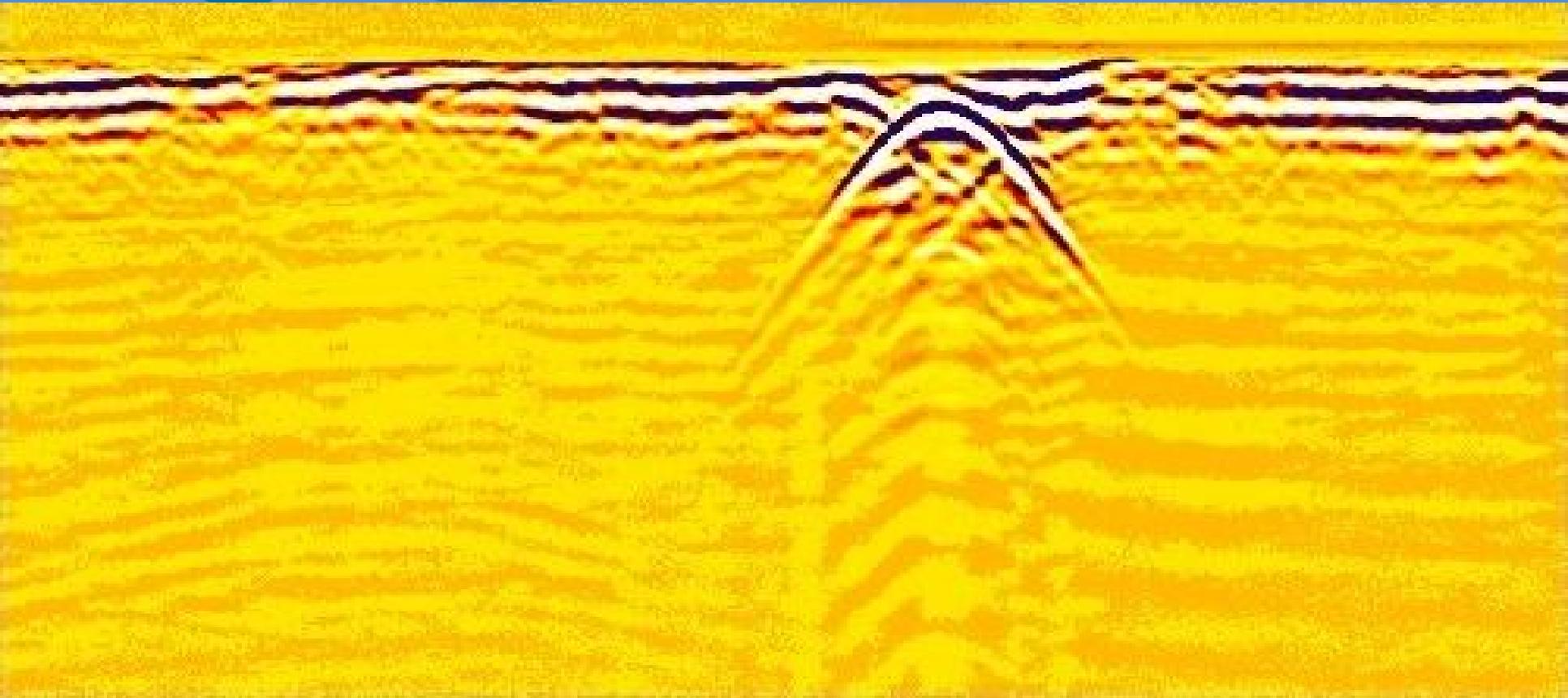
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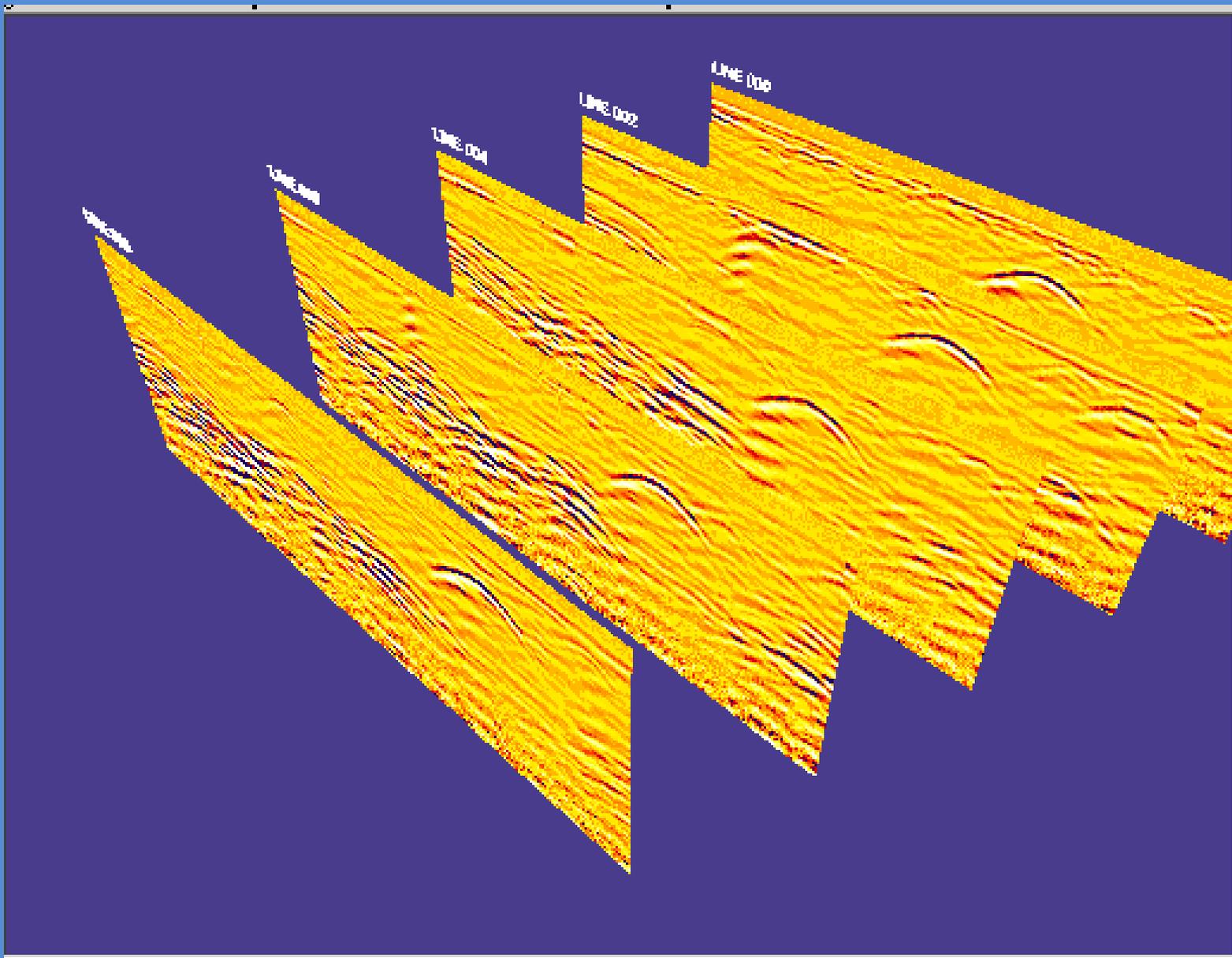
The GPR sends radar energy into the investigation medium at the centerline of the system in the direction of travel. When a target is encountered, the energy is bounced back and an image is created.





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





• Cross Sections or Slices across the width of a road. •

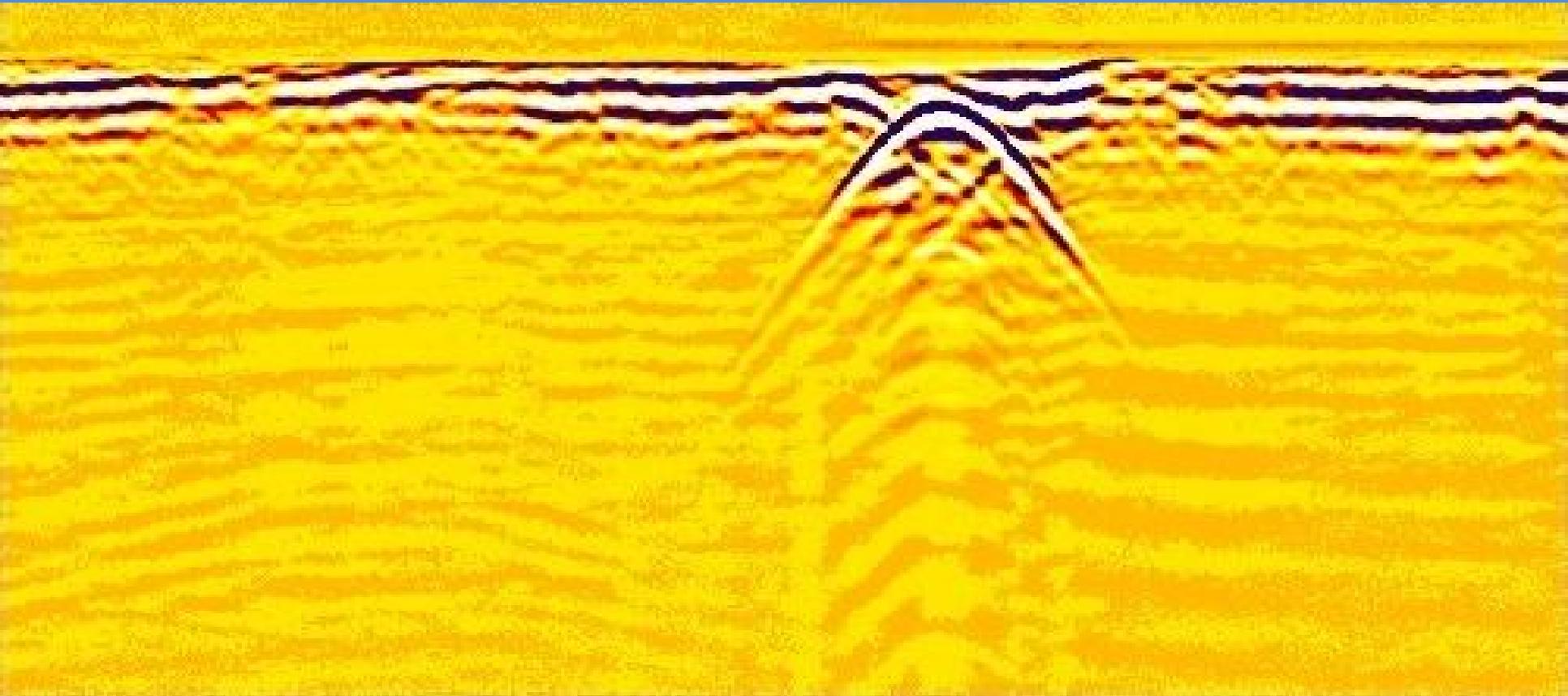
Keep in Mind that we are sending out radar “Pulses”

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



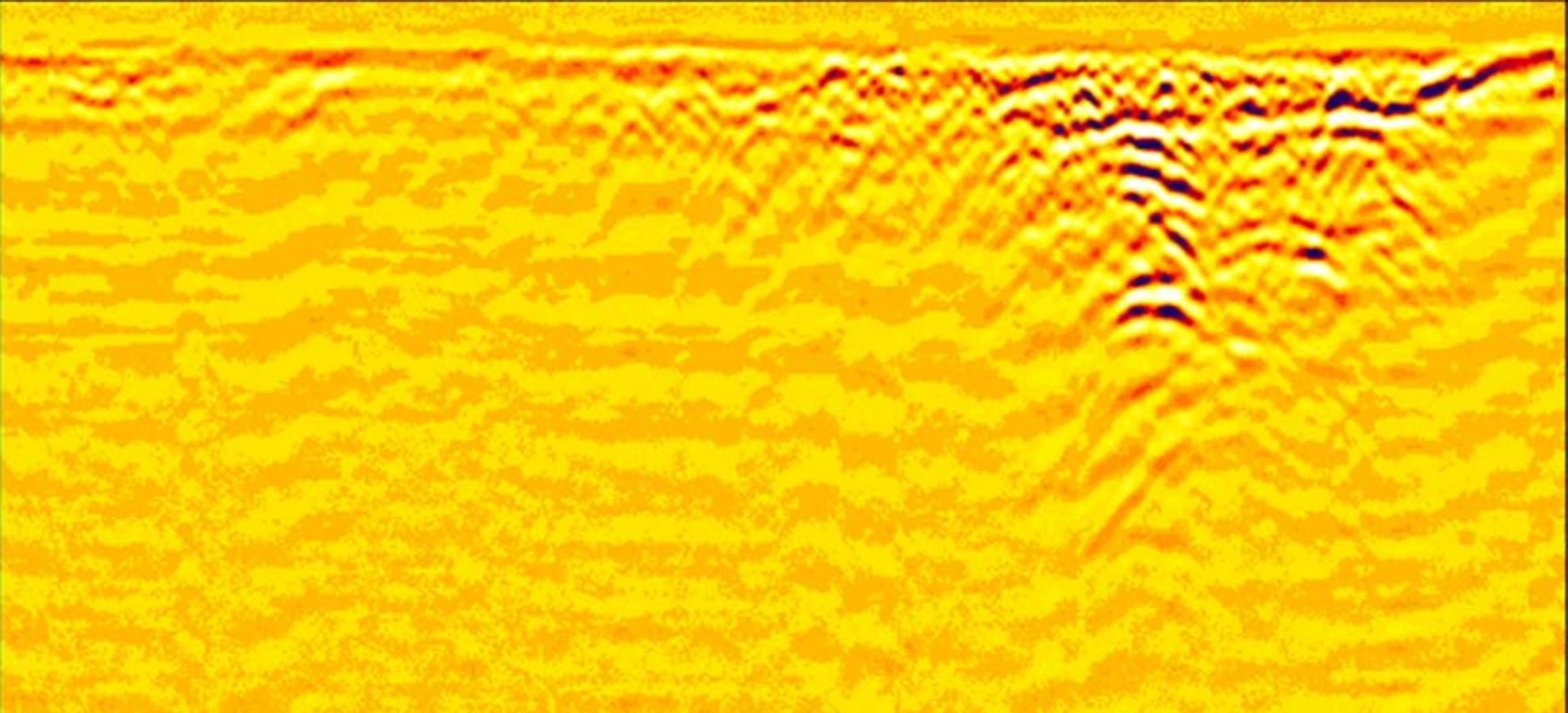
What happens when waves encounter an obstruction
i.e a boulder in the way ?





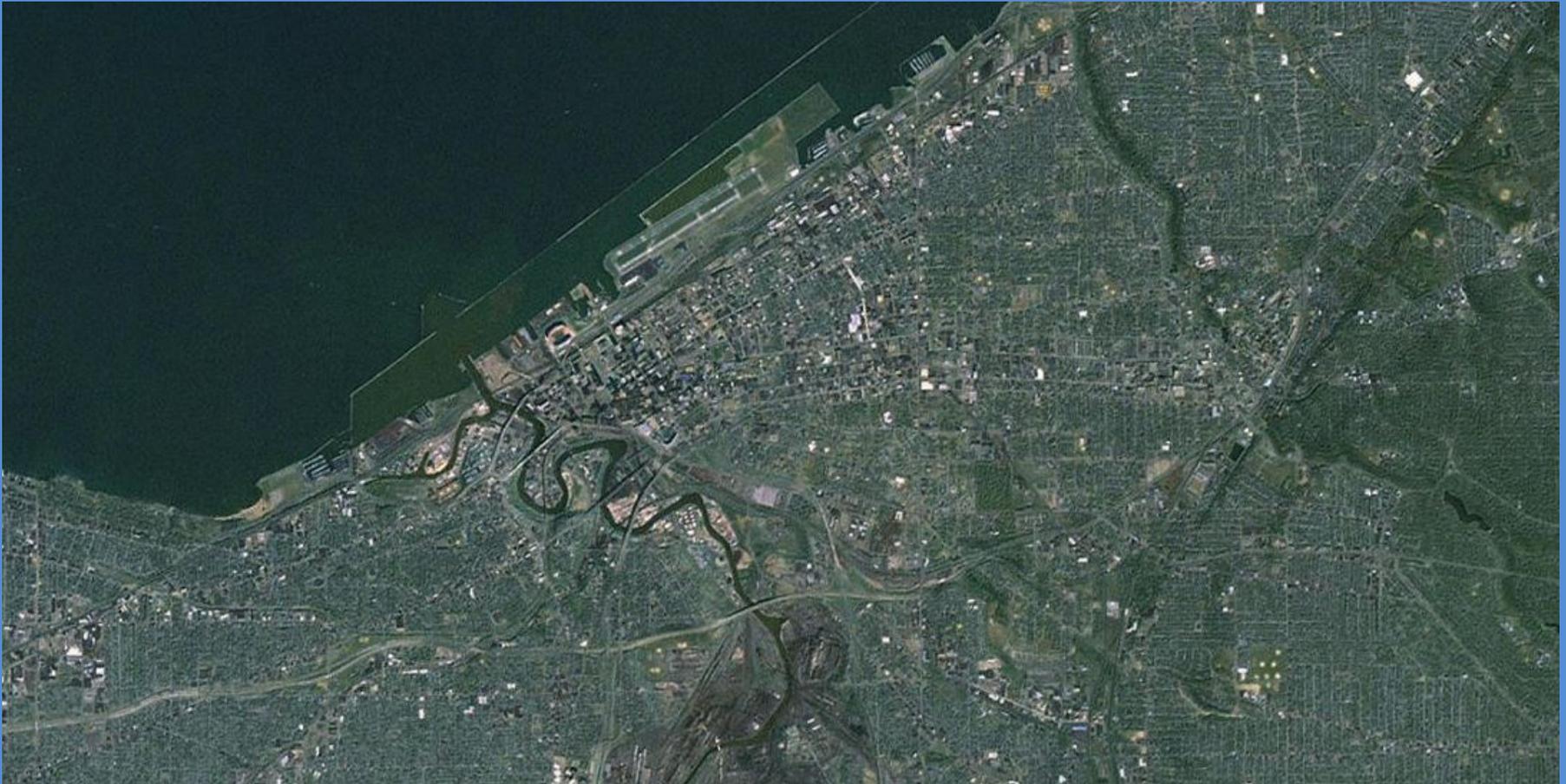
So what happens when waves approach an inlet i.e a path of lesser resistance?





The Challenge

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



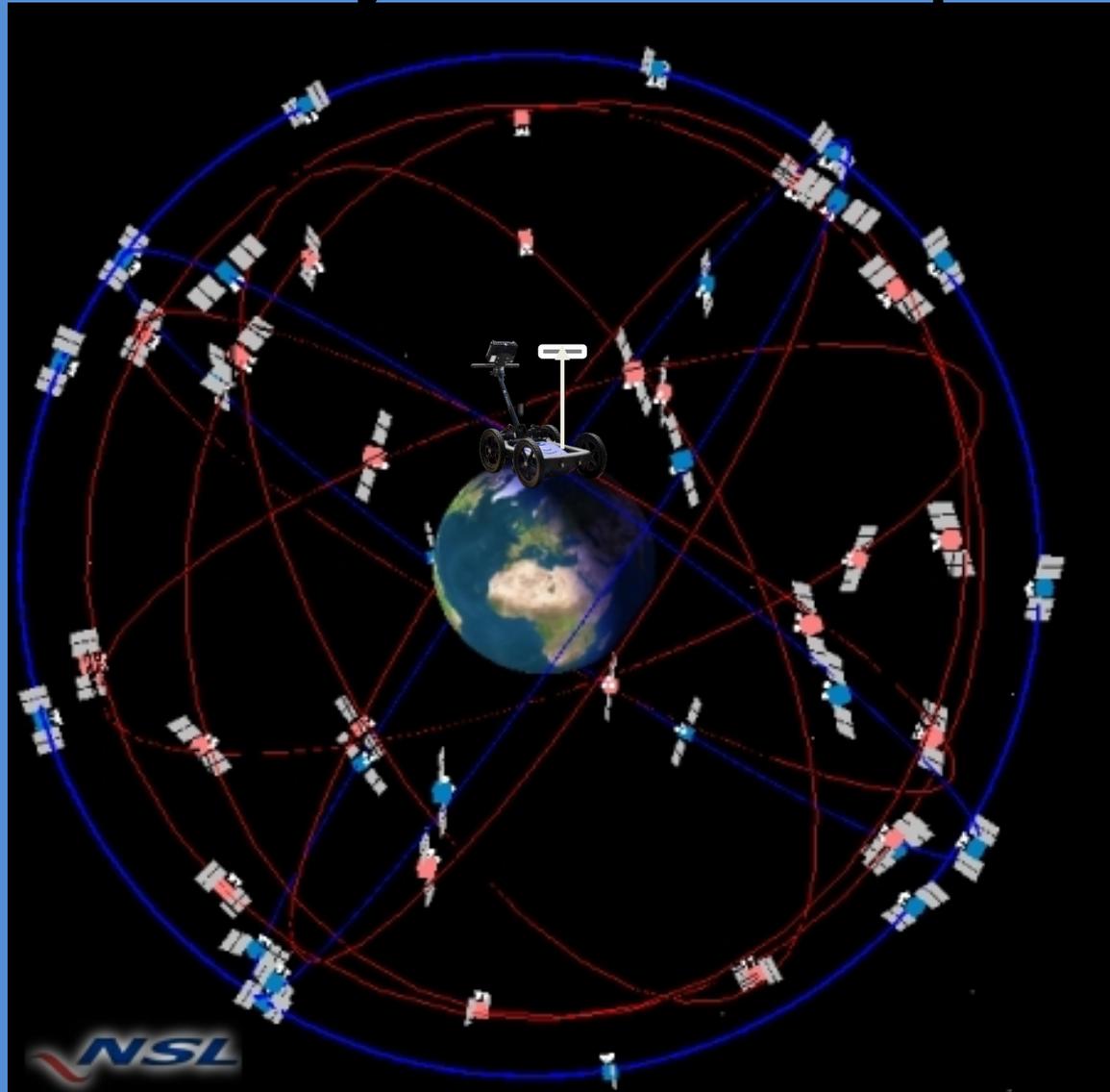
This is How it Starts



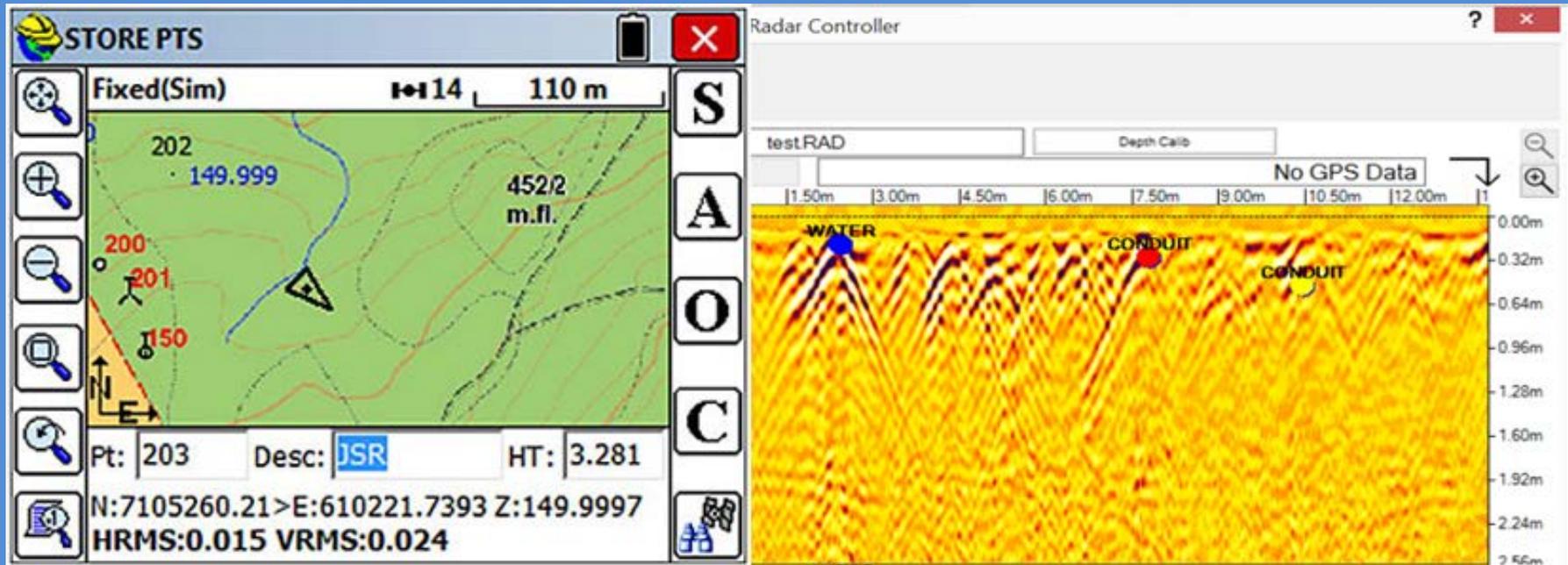
Then the “Artistes” Move in



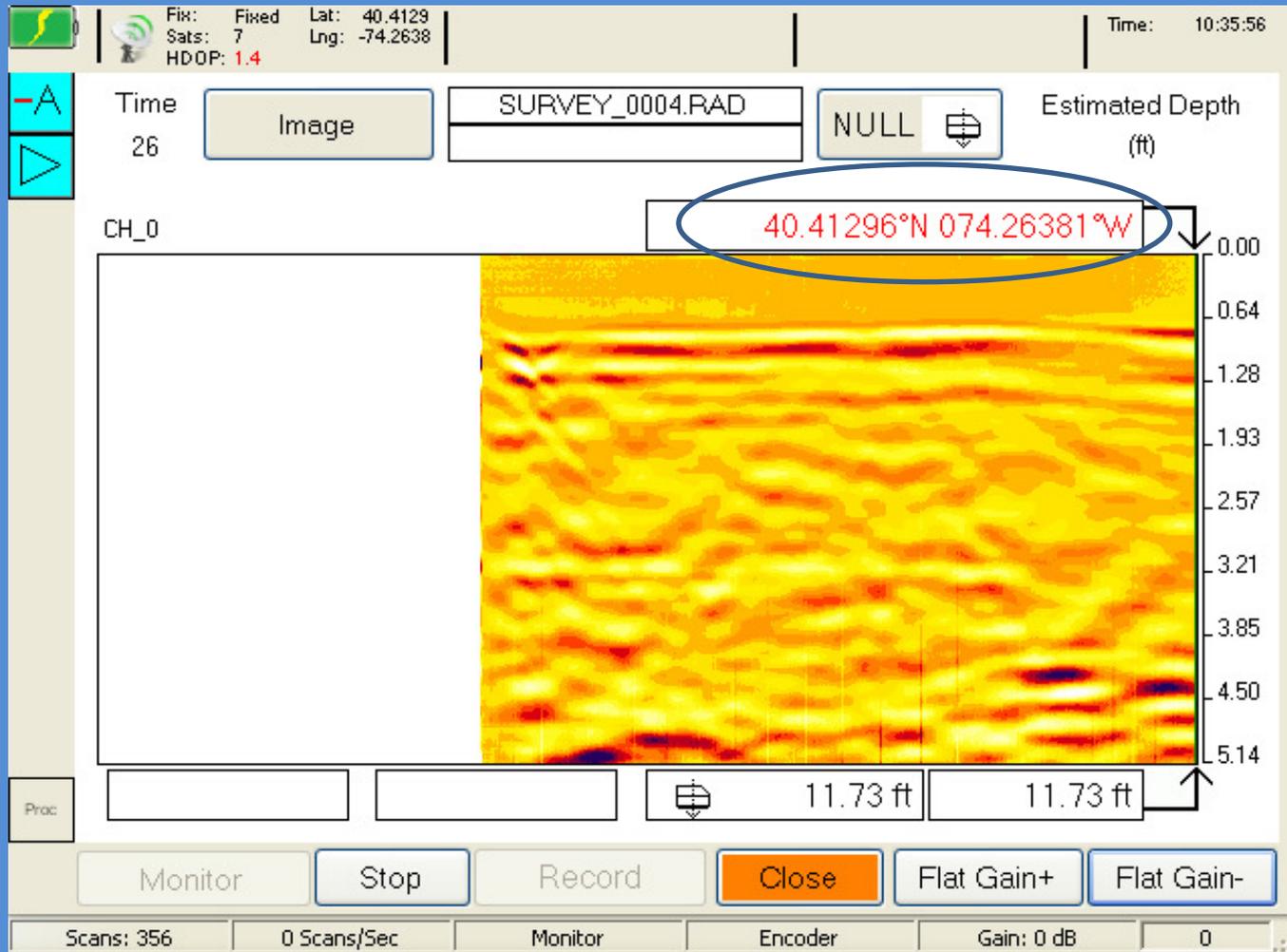
What if we combine technologies and walk away with a map?



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

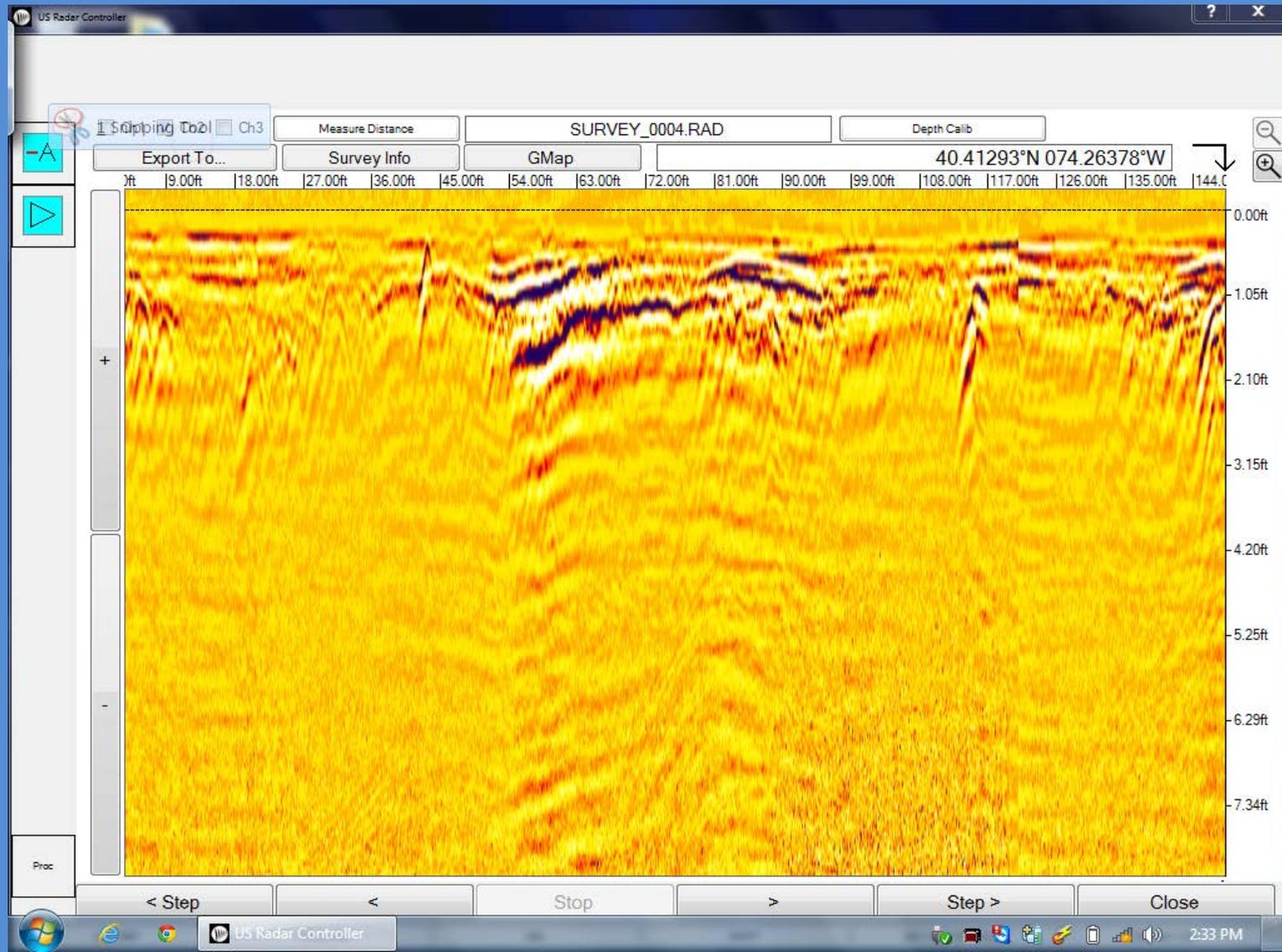


In the past couple of years we've made a quantum leap moving a great deal of processing to digital from analog processing, (radar energy is inherently analog)

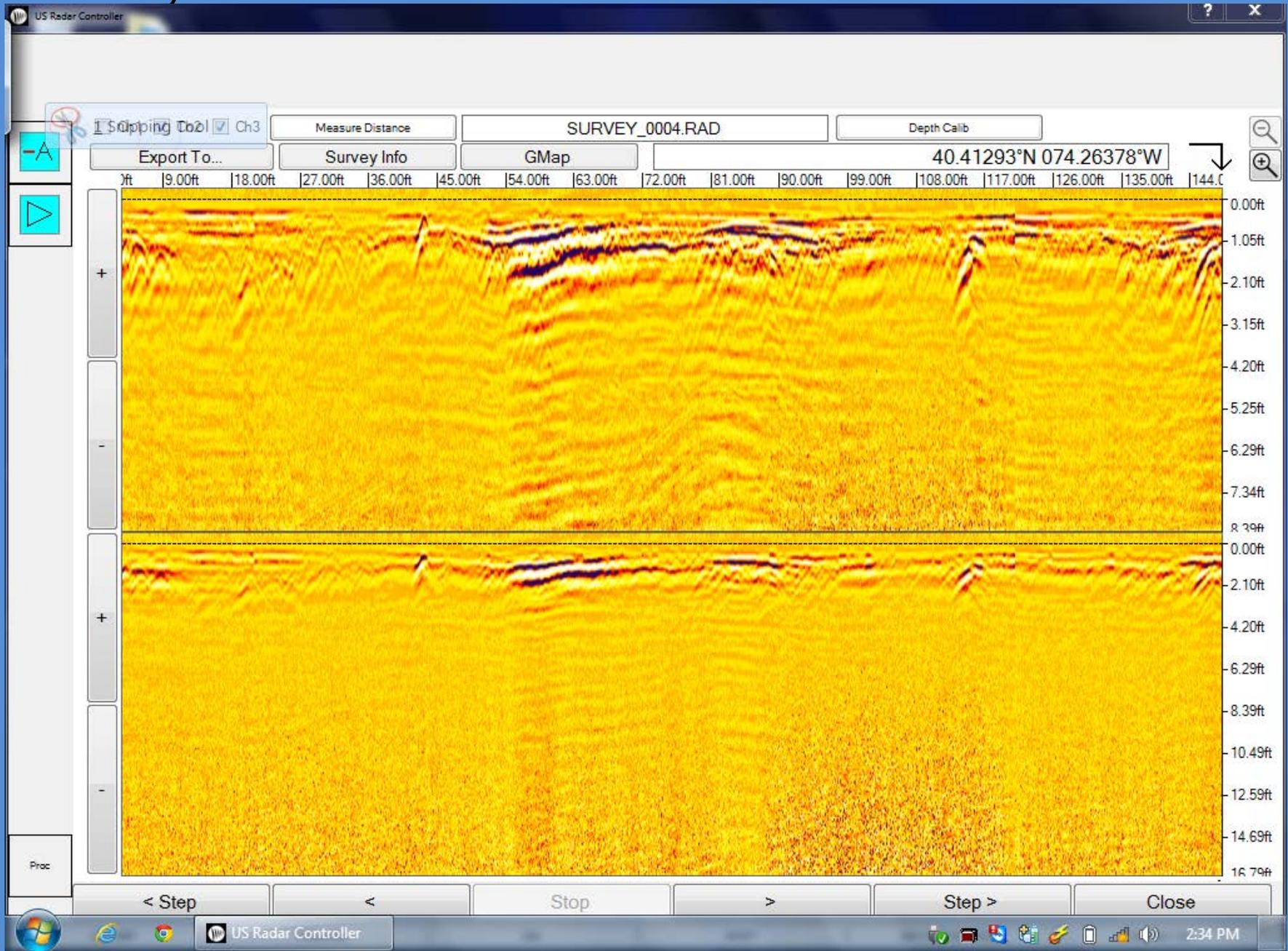
The floodgates of capabilities are creaking opening



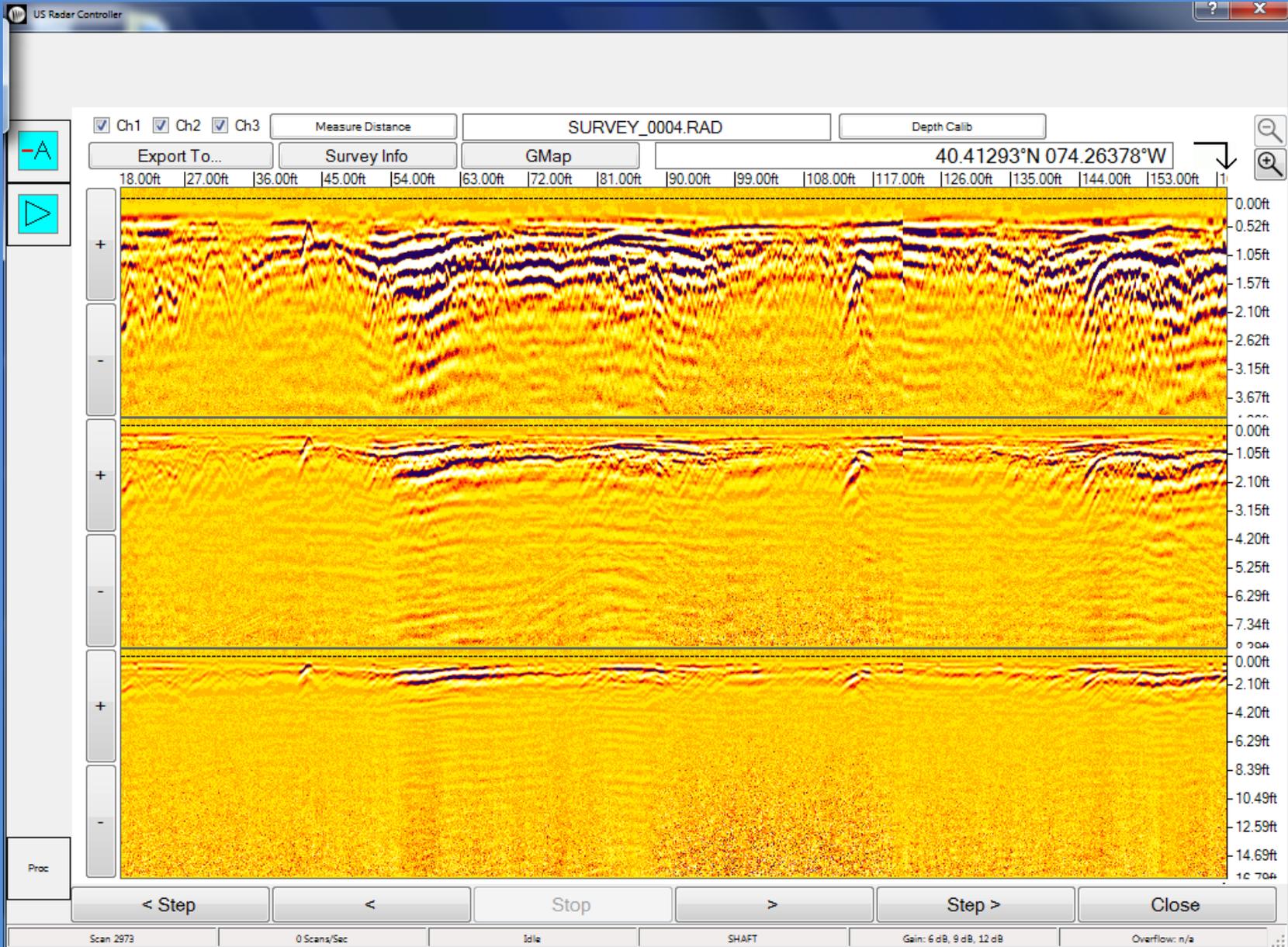
We're all familiar with single channel data



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

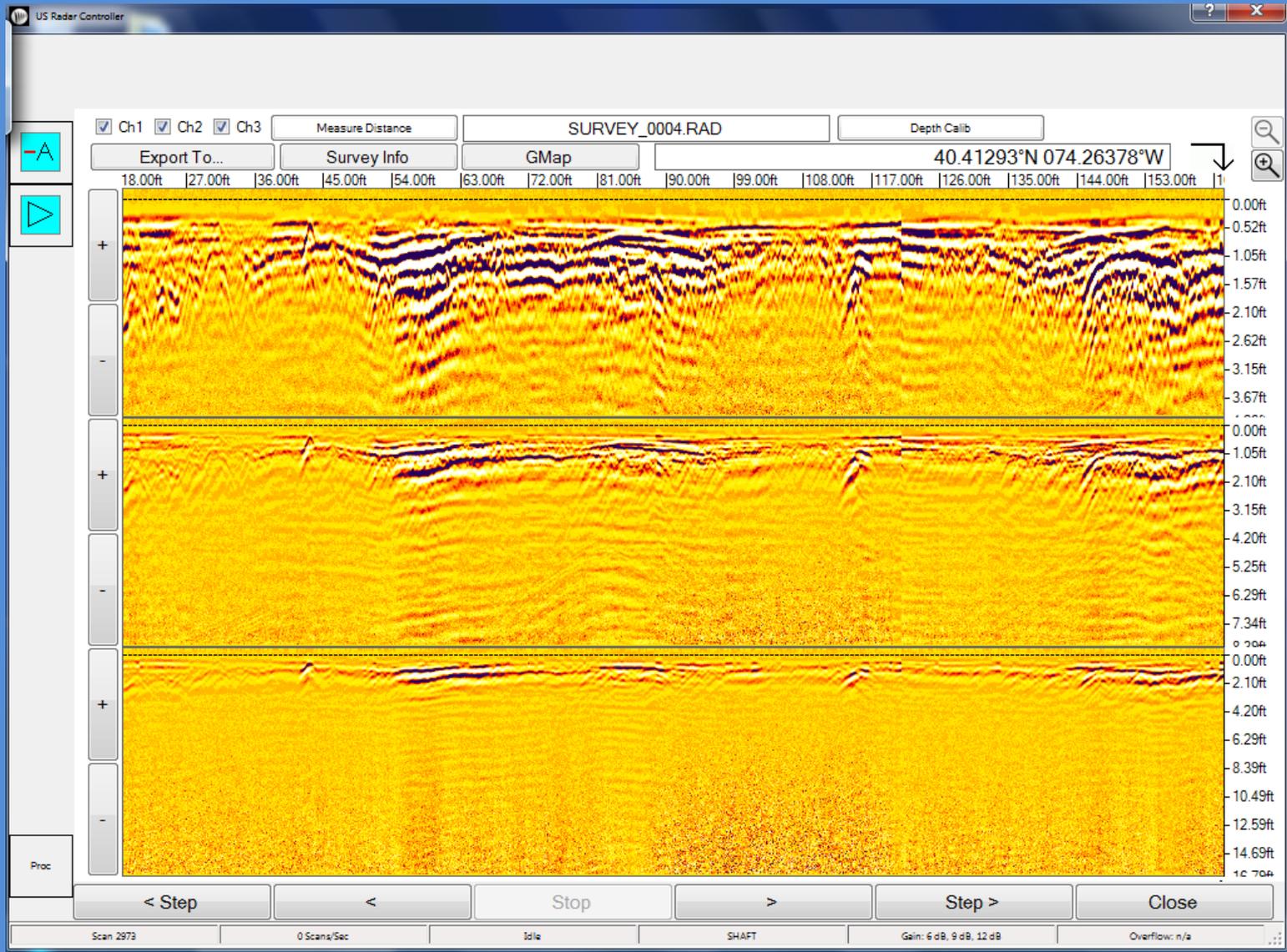
For best resolution use the shallowest available antenna that will reach desired depth,

Antenna Capabilities

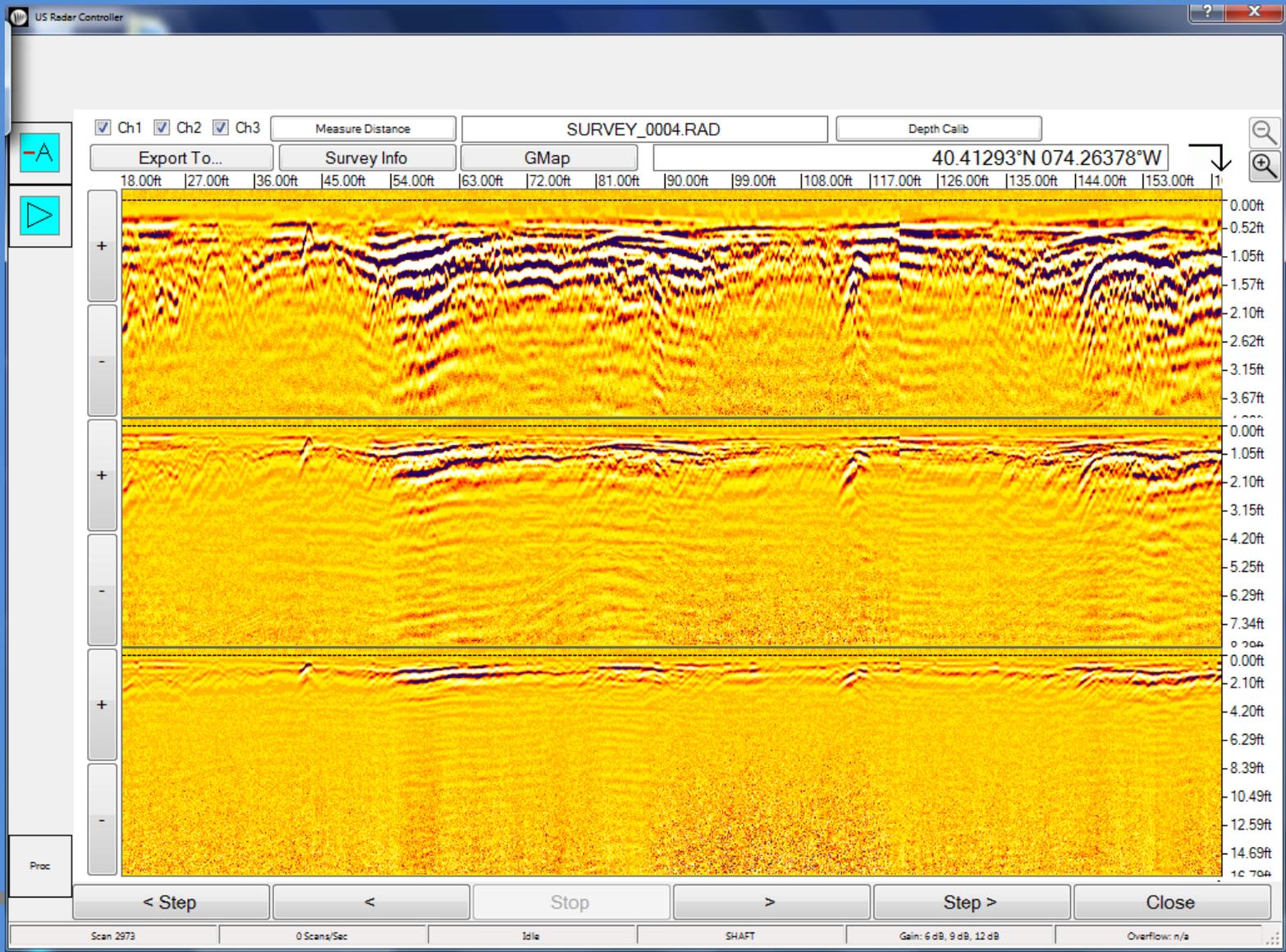
ANTENNA	Dense Wet Clay	Clean Dry Sand	EX. Of smallest object located accurately
250 MHz	4m/13ft	9m/30'	90cm/36" RCP @9m/30' 15cm/6" PVC @4m/13.3'
500MHz	1.8m/6ft	4.4m/14.7'	10cm/4" pvc @4m/13.3' 2.5cm/.5" pvc@1.8m /6'
1000 MHz	40cm/16"	1.8m/6'	2.5cm/1/2" pvc @90cm/3' Wire mesh, shallow

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

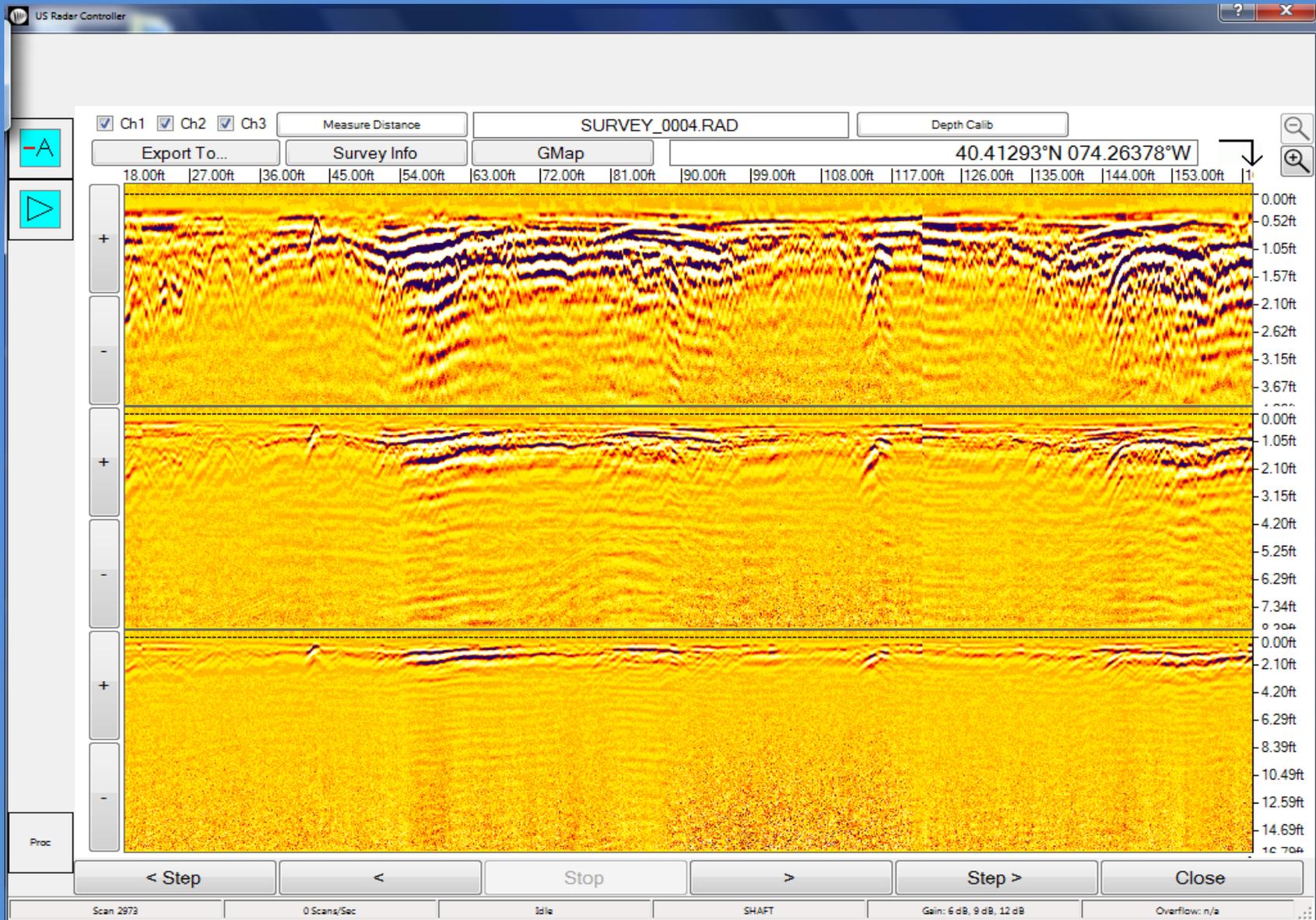
The 3 bandwidths make it very easy to recognize the most subtle changes in soil structure directing our attention toward the target



The objective is to make it easy to read and understand



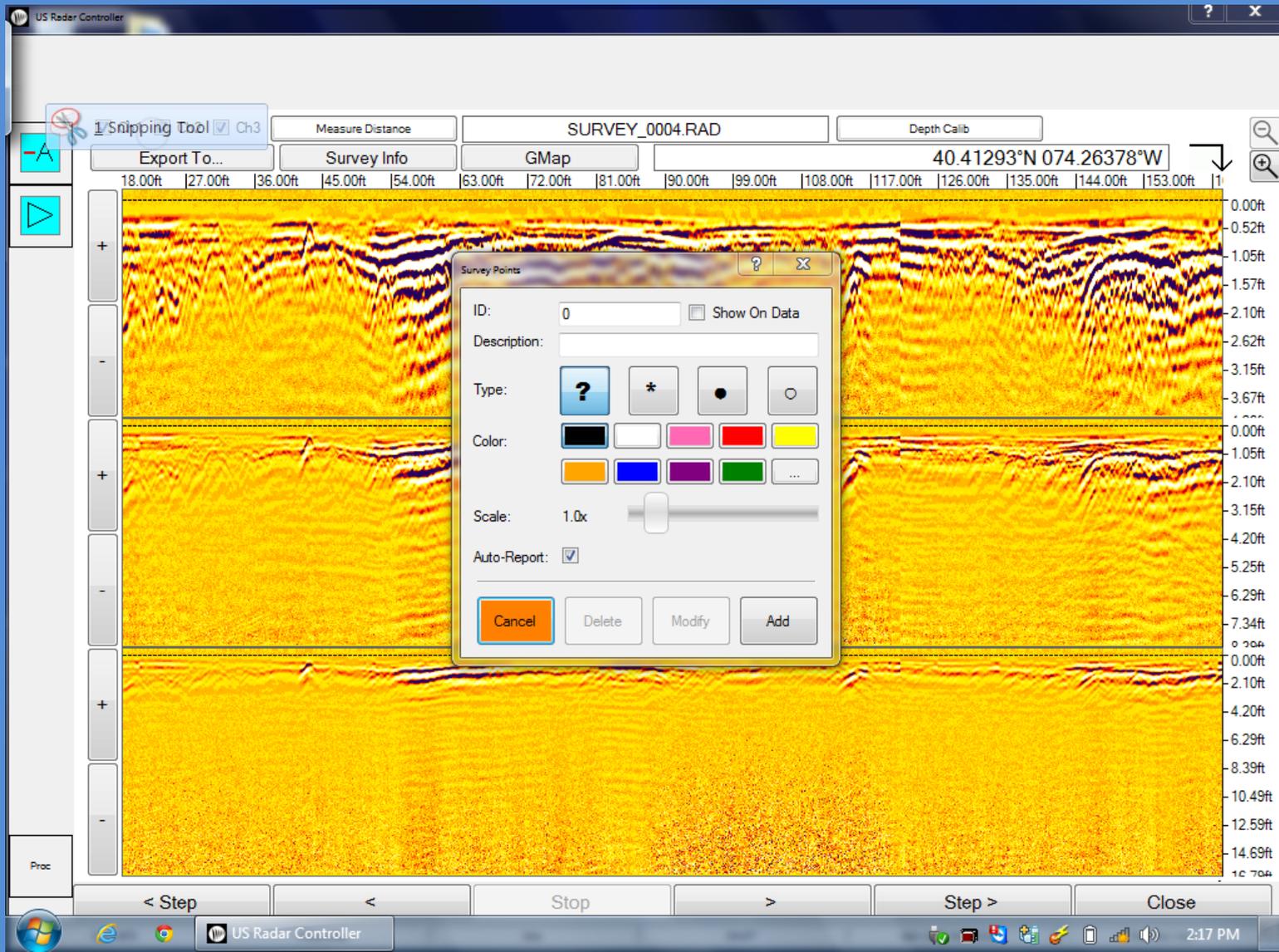
So let's do something with the findings



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

The screenshot displays the US Radar Controller software interface. The main window shows a radar scan of a subsurface area. The scan is a color-coded image with yellow and orange tones, showing various subsurface features. The scan is divided into three horizontal sections by dashed lines. The vertical axis on the right side of the scan is labeled with depths in feet, ranging from 0.00ft at the top to 14.69ft at the bottom. The horizontal axis at the top of the scan is labeled with distances in feet, ranging from 18.00ft to 153.00ft. A dialog box titled "Survey Points" is overlaid on the scan. The dialog box contains the following fields and controls:

- ID: 0123
- Description: 60kv
- Type: A dropdown menu with a question mark icon, a blue asterisk icon, a black dot icon, and a white circle icon.
- Color: A color selection palette with buttons for black, white, pink, red, yellow, orange, blue, purple, green, and a "..." button.
- Scale: 1.0x, with a slider control.
- Auto-Report:
- Buttons: Cancel, Delete, Modify, Add.

The software interface also includes a top menu bar with options like "Snapping Tool", "Ch3", "Measure Distance", "SURVEY_0004.RAD", and "Depth Calib". A status bar at the bottom shows navigation buttons: "< Step", "<", "Stop", ">", "Step >", and "Close". The Windows taskbar at the very bottom shows the time as 2:21 PM and the system tray icons.

Stopping To Bl Ch3

Measure Distance

SURVEY_0004.RAD

Depth Calib

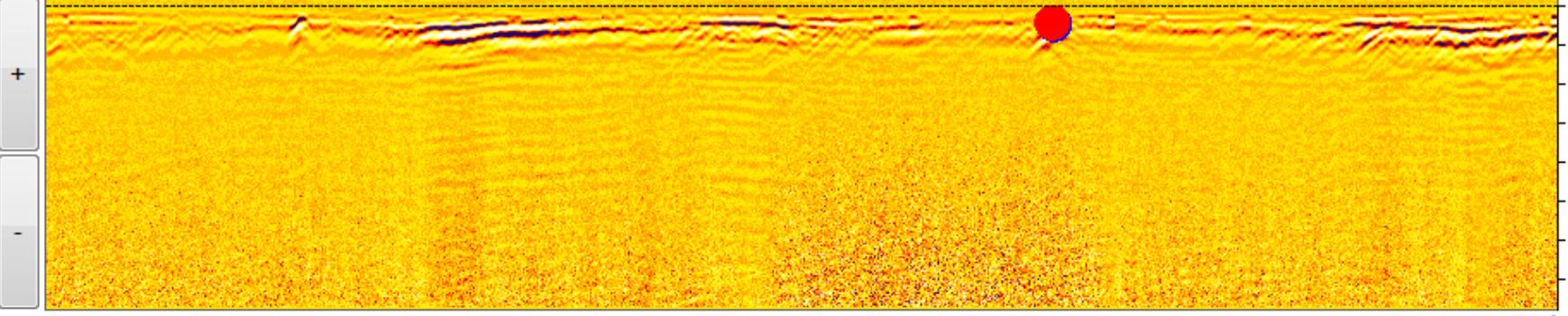
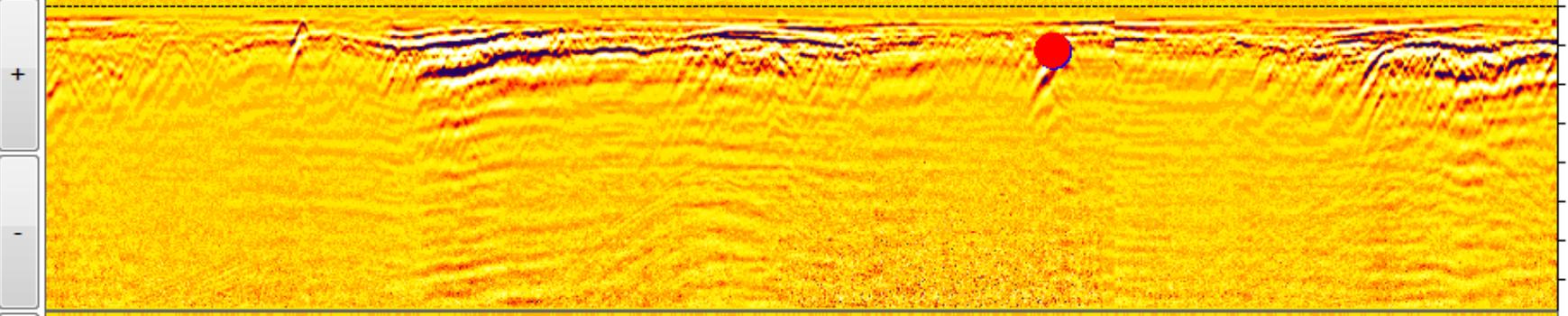
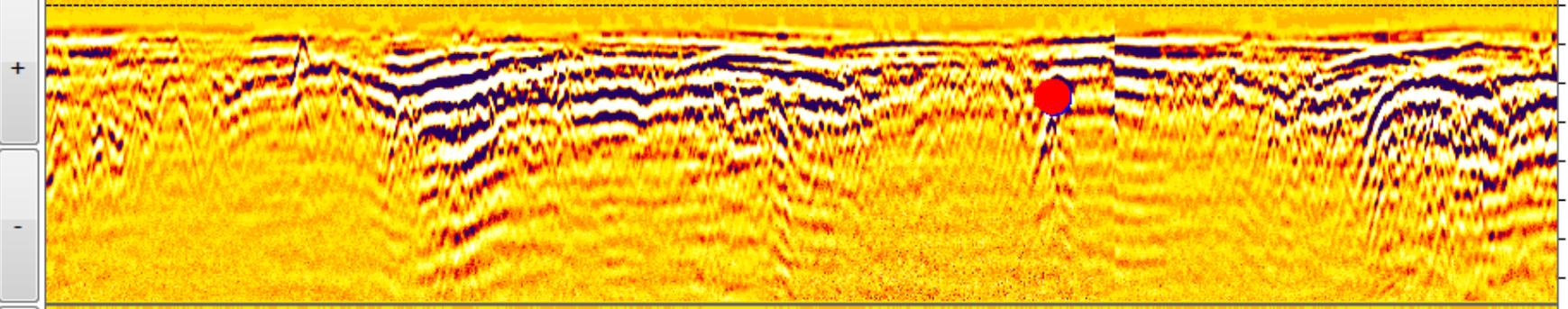
Export To...

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 | 162.00ft



< Step

<

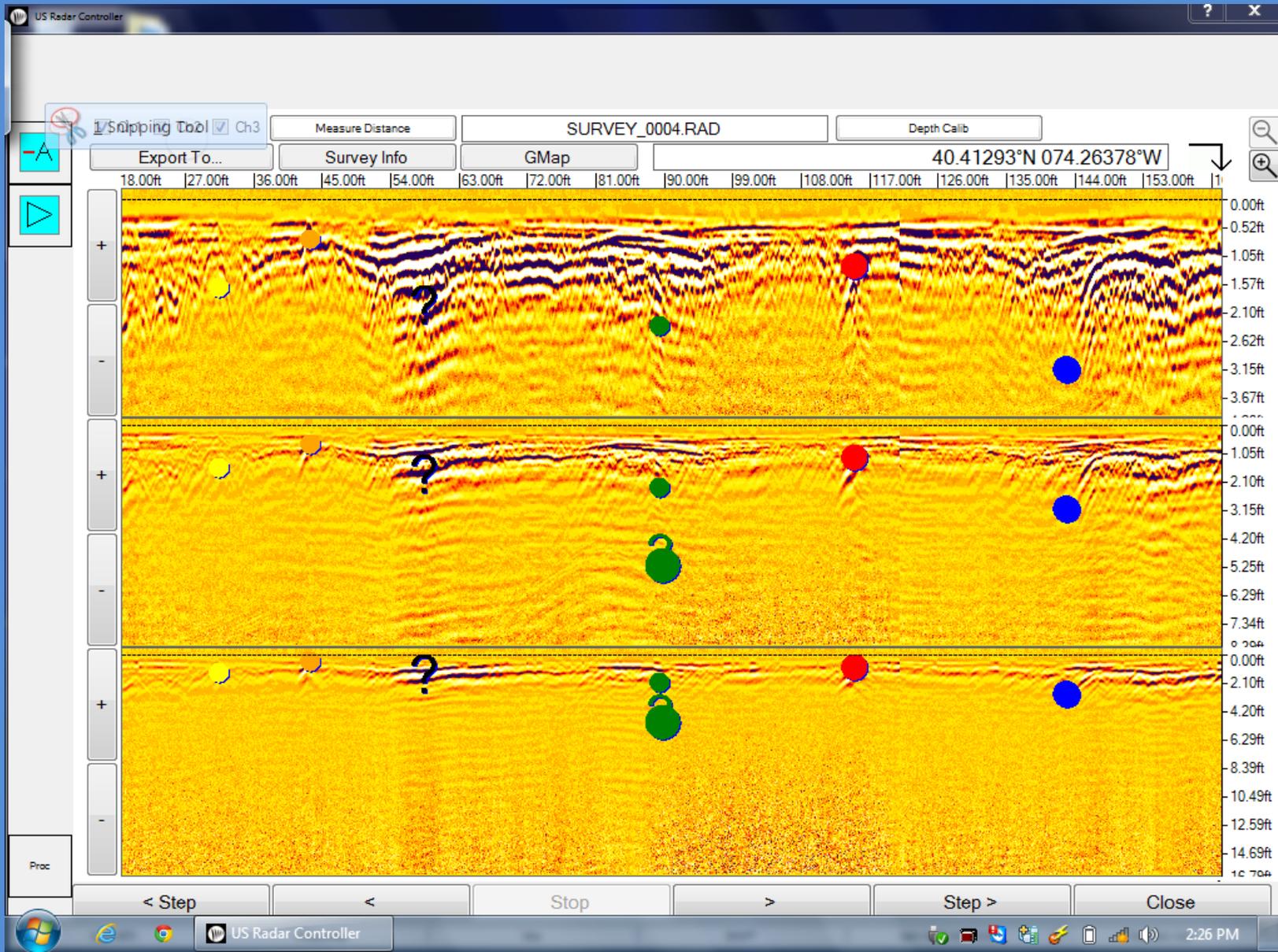
Stop

>

Step >

Close

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

The image shows the 'US Radar Controller' software interface. The main window displays a sonar scan with a depth scale on the right ranging from 0.00ft to 15.70ft. A dialog box titled 'Export To' is open in the center, asking 'What would you like to export?'. The options are:

- Screenshot Image (*.png)
- Google Earth (*.kmz)
- Video (*.avi)
- Seismic Unix (*.su)
- Auto-Report Points (*.rtf)
- Slice Image (*.png)
- Survey Point List (*.csv) (highlighted with a blue circle)
- Point Cloud
- Seg-Y (*.sgy)
- Printer

At the bottom of the dialog box is a large orange 'Cancel' button. The background software interface includes a top menu bar with 'Export To...', 'Survey Info', and 'GMap'. Below this is a coordinate display showing '40.41293°N 074.26378°W' and a distance scale from 18.00ft to 153.00ft. The main display area shows three stacked sonar scan sections with various colored markers (blue, yellow, green) overlaid on the data. The bottom of the software window has navigation buttons: '< Step', 'Step >', and 'Close'. The Windows taskbar at the very bottom shows the time as 2:27 PM.

Pick the data you want to transfer

US Radar Controller

Stopping 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
3.15ft
3.67ft
4.20ft
4.72ft
5.25ft
5.77ft
6.29ft
6.81ft
7.34ft
7.86ft
8.39ft
8.91ft
9.43ft
9.95ft
10.48ft
11.00ft
11.52ft
12.04ft
12.57ft
13.09ft
13.61ft
14.13ft
14.65ft
15.17ft

Proc

< Step < Stop > Step > Close

Survey Points

Please select the information you would like to export

- Number
- ID
- Type
- Scan
- Sample
- GPS_Latitude
- GPS_Longitude
- GPS_Elevation_ft
- Real_Elevation_ft
- Estimated_Depth_ft
- Description

Cancel OK

Files are copied and transferred via usb

The screenshot shows a file transfer utility window with the following components:

- Source:** Path is C:\SPR_DATA. A list of files is shown, including SET001.SET through SET005.SET, and SURVEY_0001.RA1 through SURVEY_0007.RA2.
- Destination:** Path is C:\SPR_EXPORT. A list of files is shown, including SURVEY_0002-000.png through SURVEY_0013-IMG000.png. The file SURVEY_0004-000.csv is selected.
- Attached USB Drives:** Shows 'Generic volume (D:)' and 'USB Mass Storage Device 6733.16MB Available'. Buttons for 'Refresh' and 'Eject' are present.
- Progress:** Shows 'Current File: <None>'. A progress bar is visible, and a large green button with the text '>>>>Copy>>>>' is highlighted.
- Close:** A large orange button labeled 'Close' is at the bottom.

At the bottom of the screen, the Windows taskbar shows the 'Copy To USB' utility icon, the system tray with various icons, and the time '2:32 PM'.

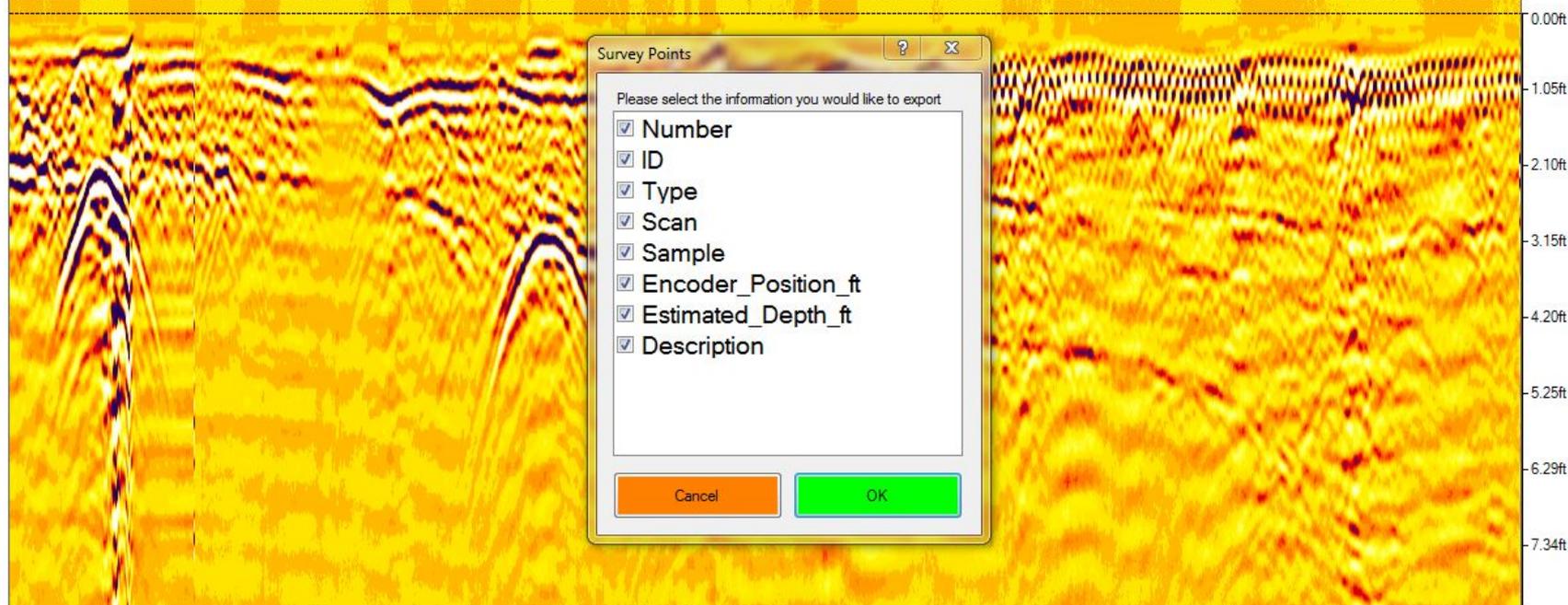
✘ Fix: N/A Lat: 0 Speed: 0.00ft/s Flat Gain: 0 dB Time: 15:35:48 ?
 Sats: 0 Lng: 0 Channels: 1



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 | 94.5ft

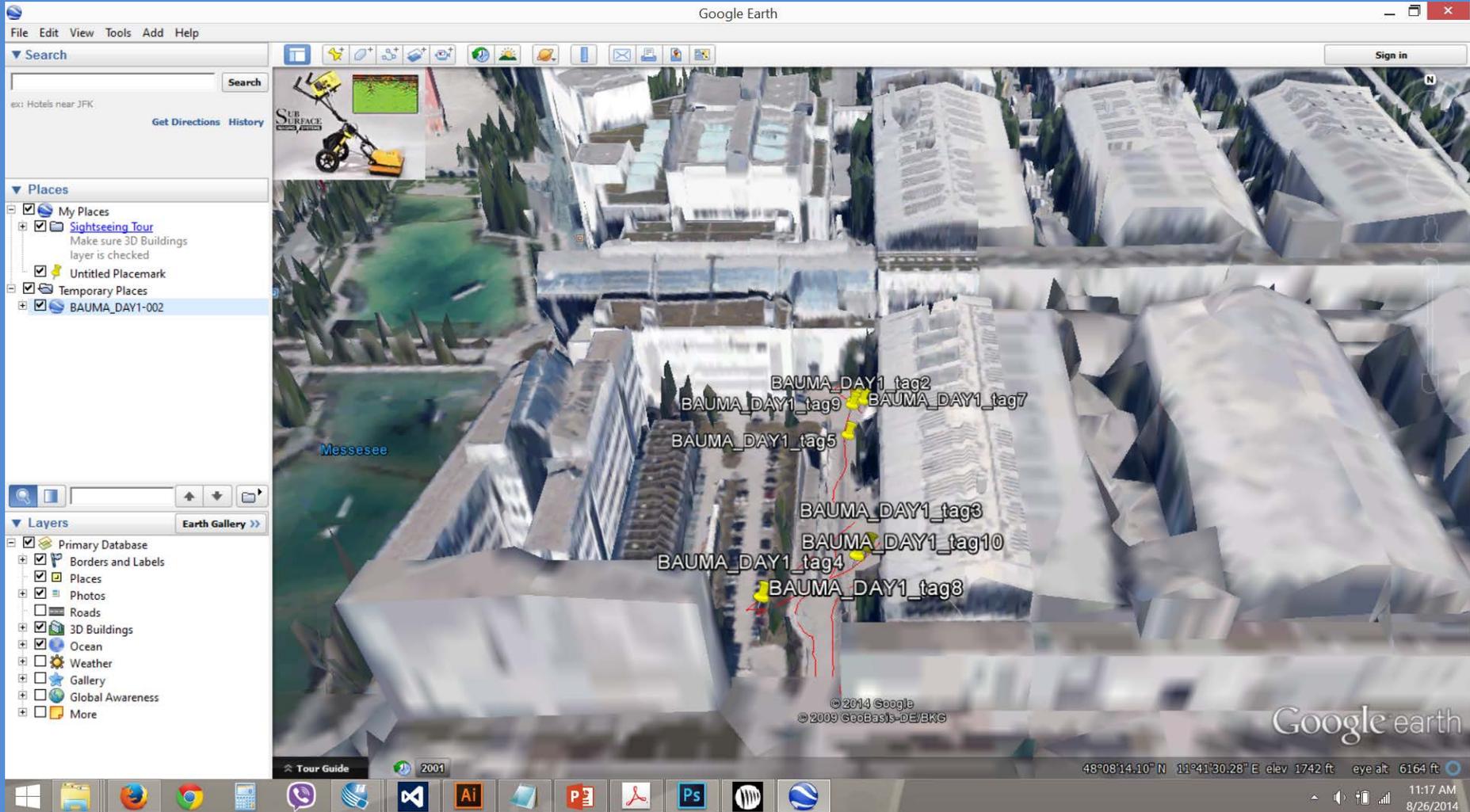


Proc Playback Speed
┌
└
 96.62 ft ↑

< Step
<
Stop
>
Step >
Close
Flat Gain +
Flat Gain -

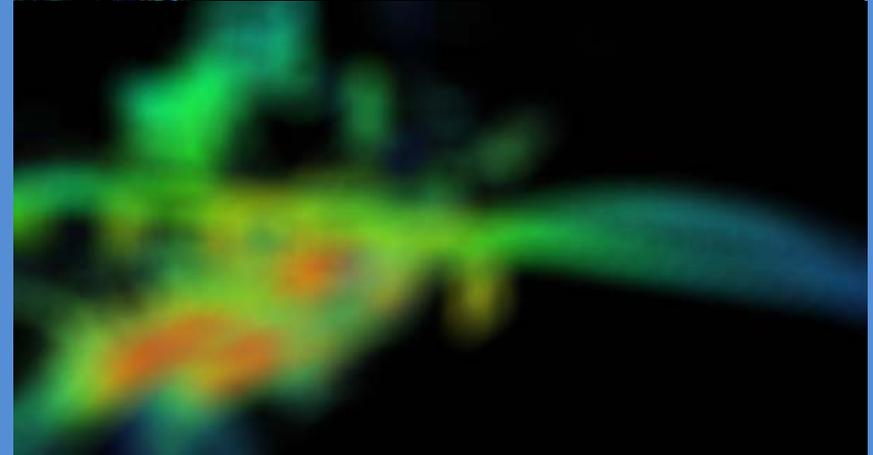
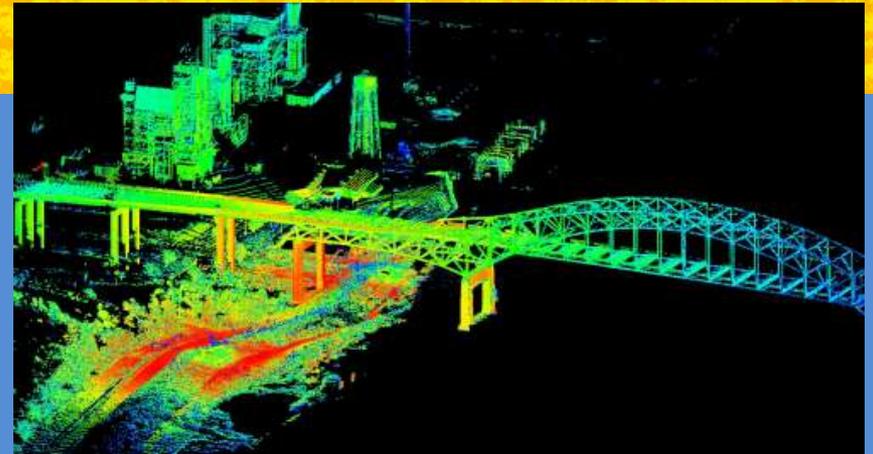
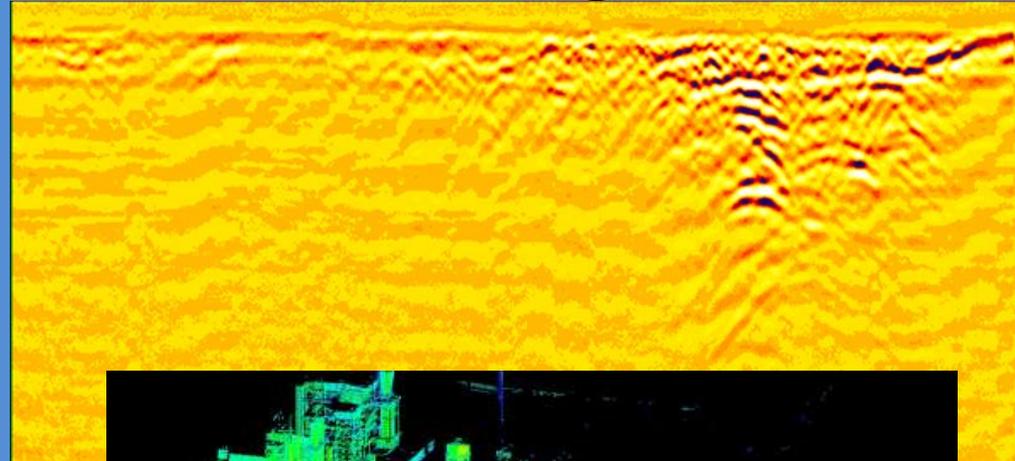
Scan 1156 0 Scans/Sec Idle SHAFT Gain: 0 dB Overflow: n/a

Or Google Earth...



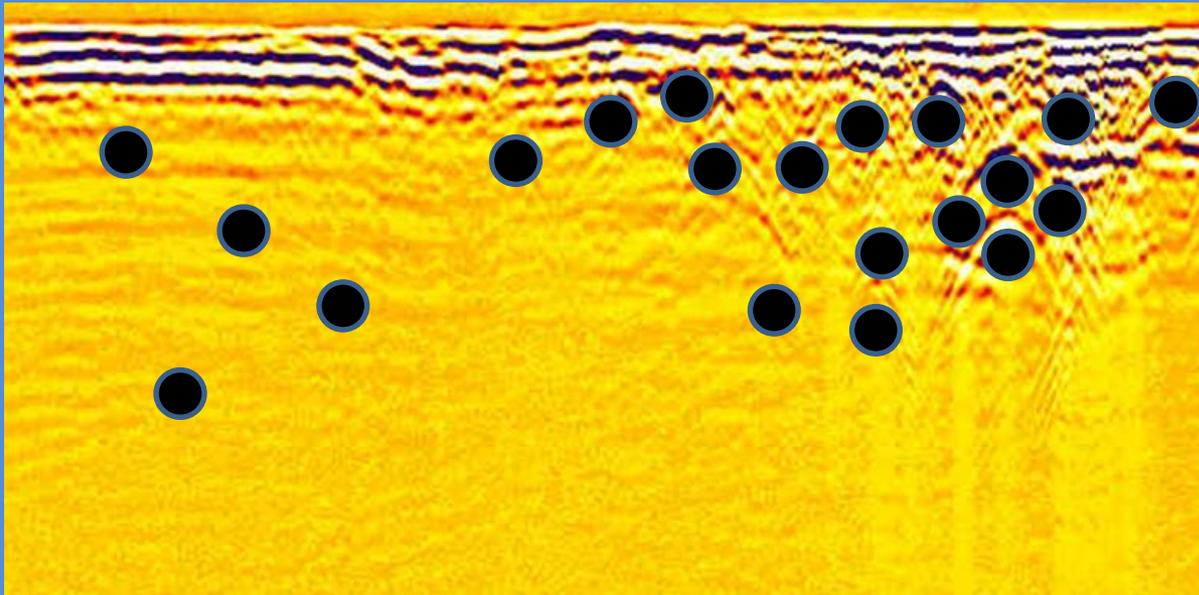
There are some challenges

- 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. .

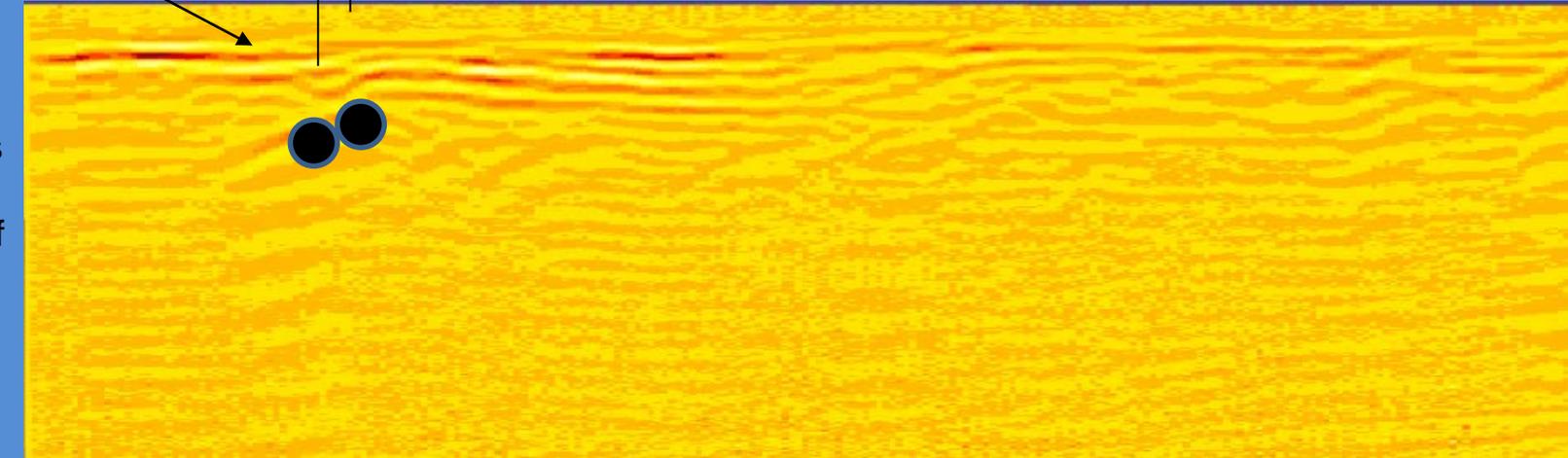
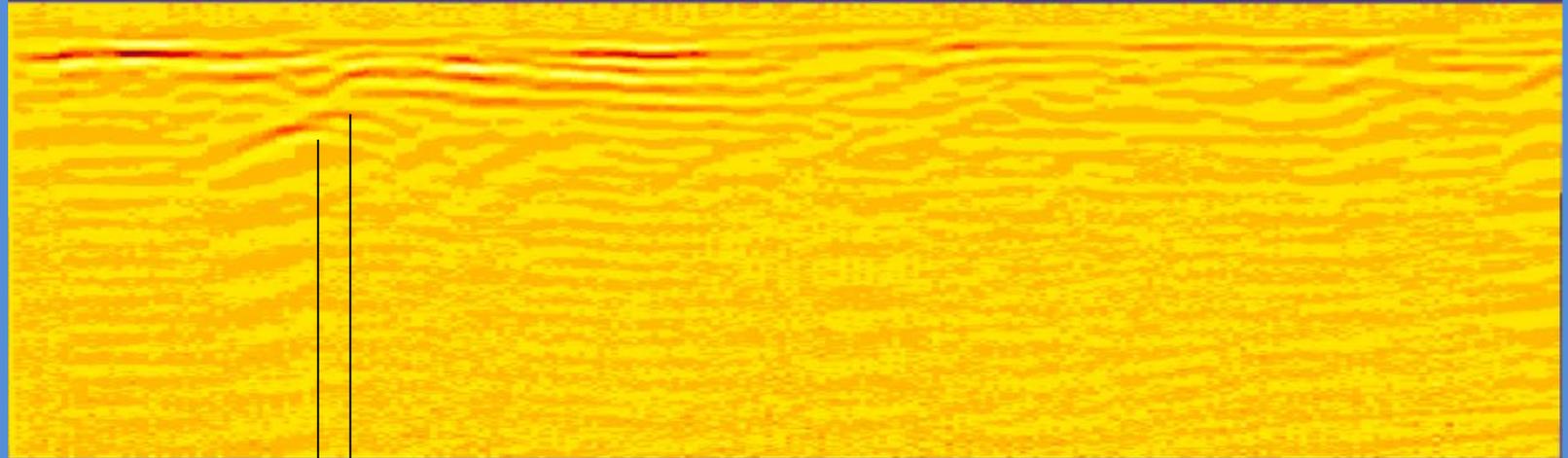


Automatic conversion is the holy grail.

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...

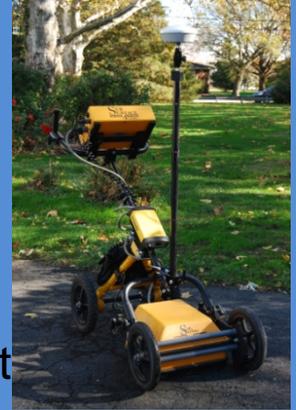
1) Treat the gpr like a data collector using a gps unit and manually select points on the cross-section data in real time in the field. Export these points to some sort of survey/civil software and connect just as we would with normal land survey data

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: \pm 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

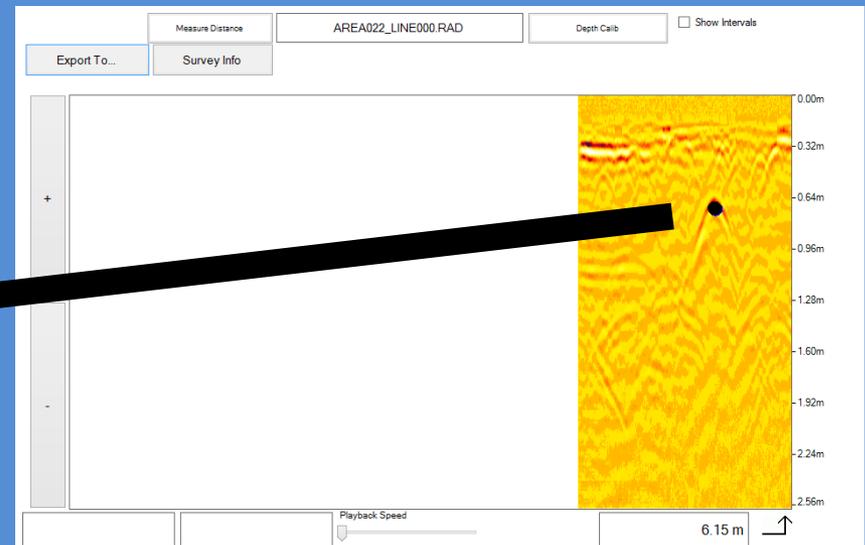
Treat the gpr like a data collector using a gps unit and manually select points on the cross-section data in real time in the field.

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.

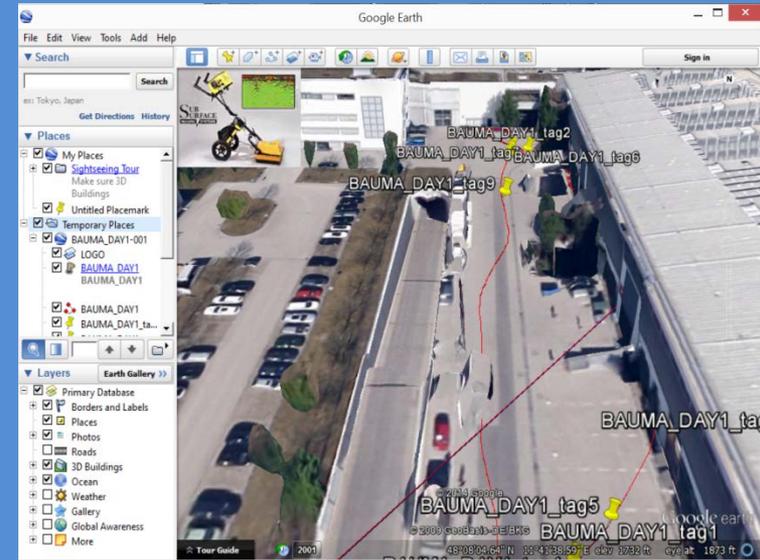


Approach #1 – Treat the Radar like a data collector Mapping Applications

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:

- Native Google Earth survey data collection & basic connect the dots drafting
- Split screen view as-builts and collected vector survey data while collecting radar data
- Collect points and annotate lines and features while recording radar data
- Caches Google Earth tiles (no internet Connection required for satellite or map data)
- Uploads and downloads work from the cloud-great for coordinating amongst many crews (requires internet connection)
- .kmz deliverables



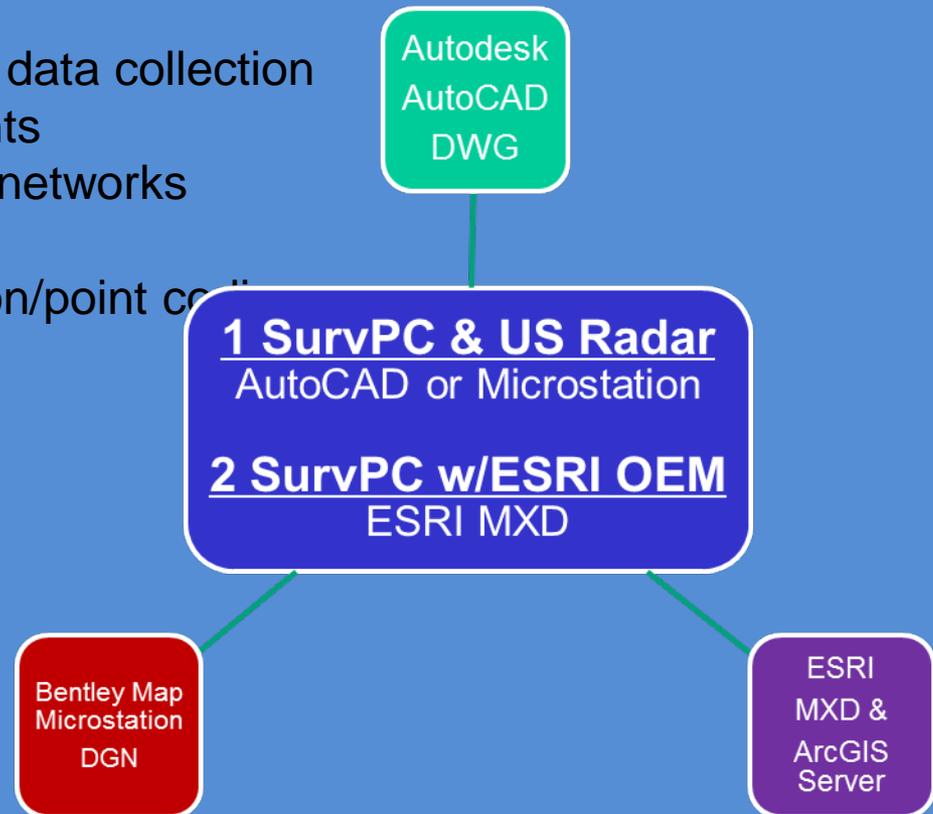
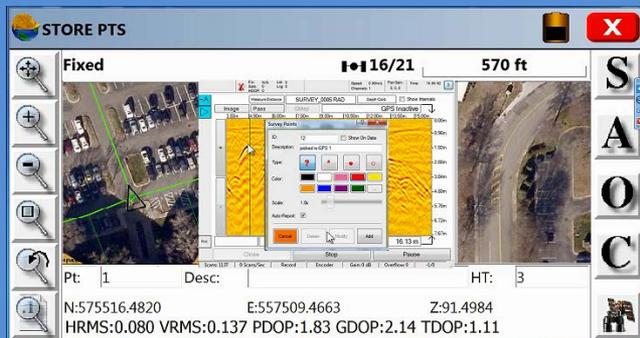
Approach #1 – Treat the Radar like a data collector

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 collection

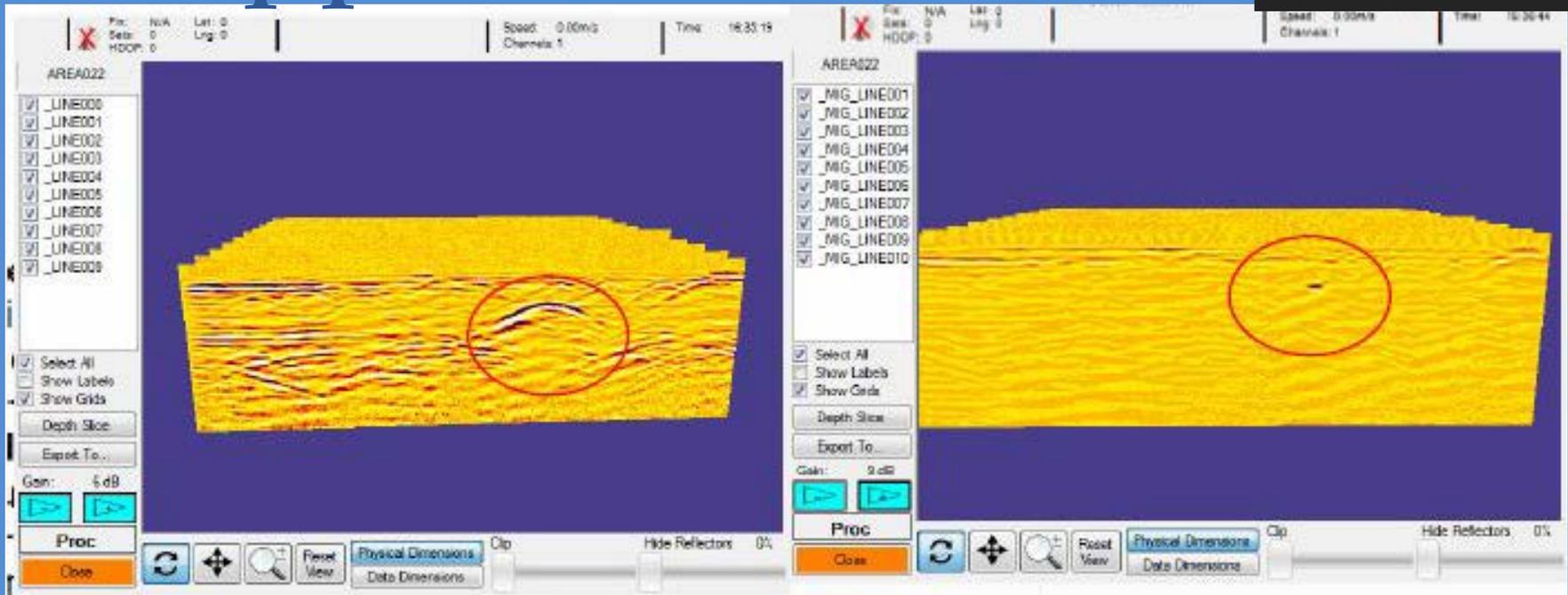


Approach #1-Treat the radar like a data collector.

End result when combined with land survey information



Approach #3-3D Data



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

Two notes:

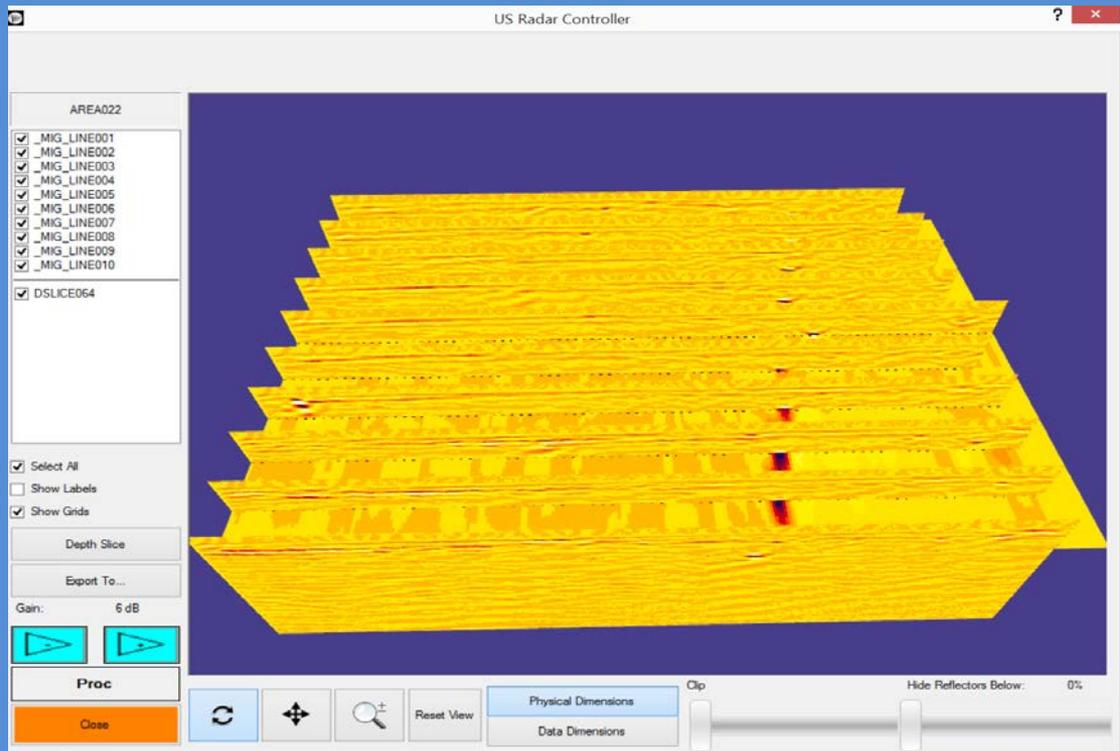
1) Generally it is only possible to post-process data subtractively (background can be removed, but things which do not appear cannot be added). No CSI-style image enhancements in the real world.

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)

The screenshot displays the 'US Radar Controller' software interface. At the top left, a text box indicates 'Sample Range: 18-154' and 'Depth Range: 0.06-0.47m'. Below this, there are two tabs: 'Depth Slice' and 'Peak Map', with 'Peak Map' currently selected. The interface is divided into two main sections: 'Depth Slice' on the left and 'Peak Map' on the right. The 'Depth Slice' section includes a vertical slider and several directional buttons. The 'Peak Map' section includes a vertical slider, a refresh button (a green circular arrow), and several directional buttons. At the bottom left, there is a 'Proc' button, a 'Close' button, and an 'Export To...' button. The 'Gain' is set to '9 dB'. The main visualization area on the right shows a 3D radar survey bitmap with a color scale from yellow (top) to red (bottom), overlaid with a grid. The data shows vertical, wavy patterns of high intensity (red) against a lower intensity background (yellow/orange).

Approach #3-3D Data

Fix: N/A Lat: 0
Sats: 0 Lng: 0
HDOP: 0

Speed: 0.00m/s
Channels: 1

Time: 17:08:25

SET033

- MIG_LINE02
- MIG_LINE03
- MIG_LINE04
- MIG_LINE05
- MIG_LINE06
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- MIG_LINE79
- MIG_LINE80
- MIG_LINE81
- DSLICE082

Select All
 Show Labels
 Show Grids

Depth Slice

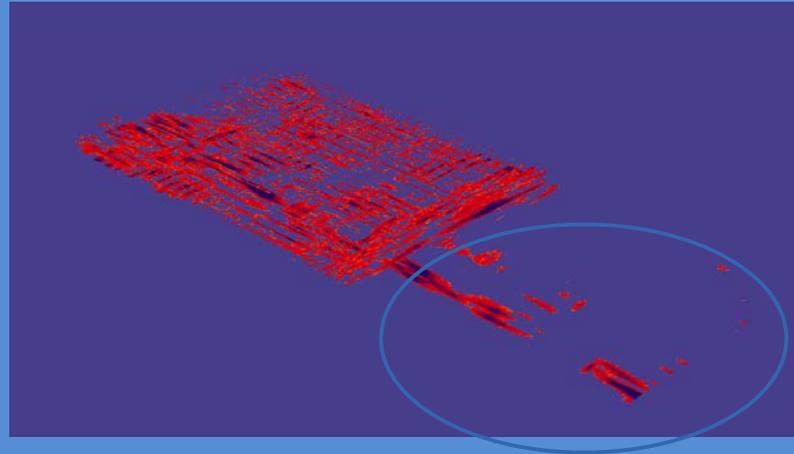
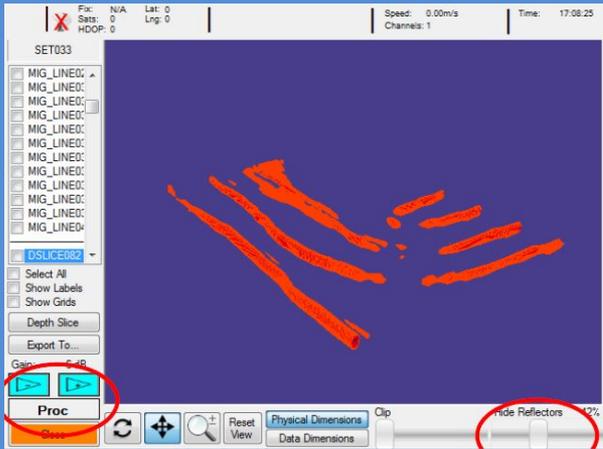
Export To...

Gain: 6 dB

Clip

12%

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.

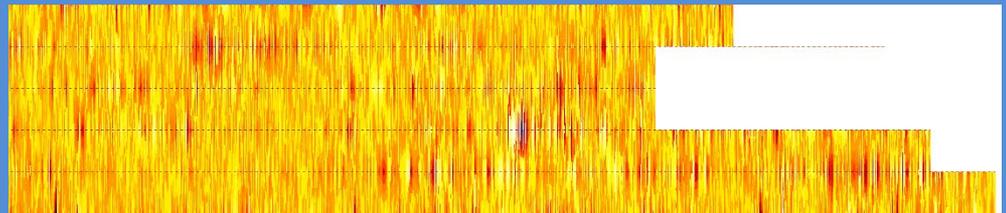
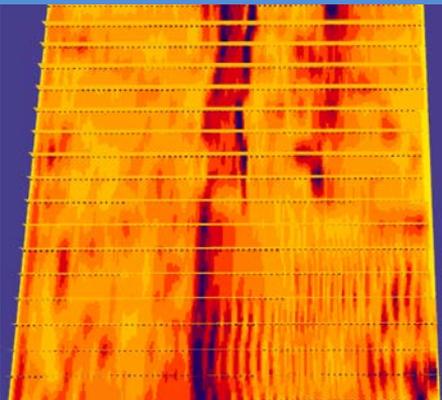
Here are real world examples of good, medium, and poor data.

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.

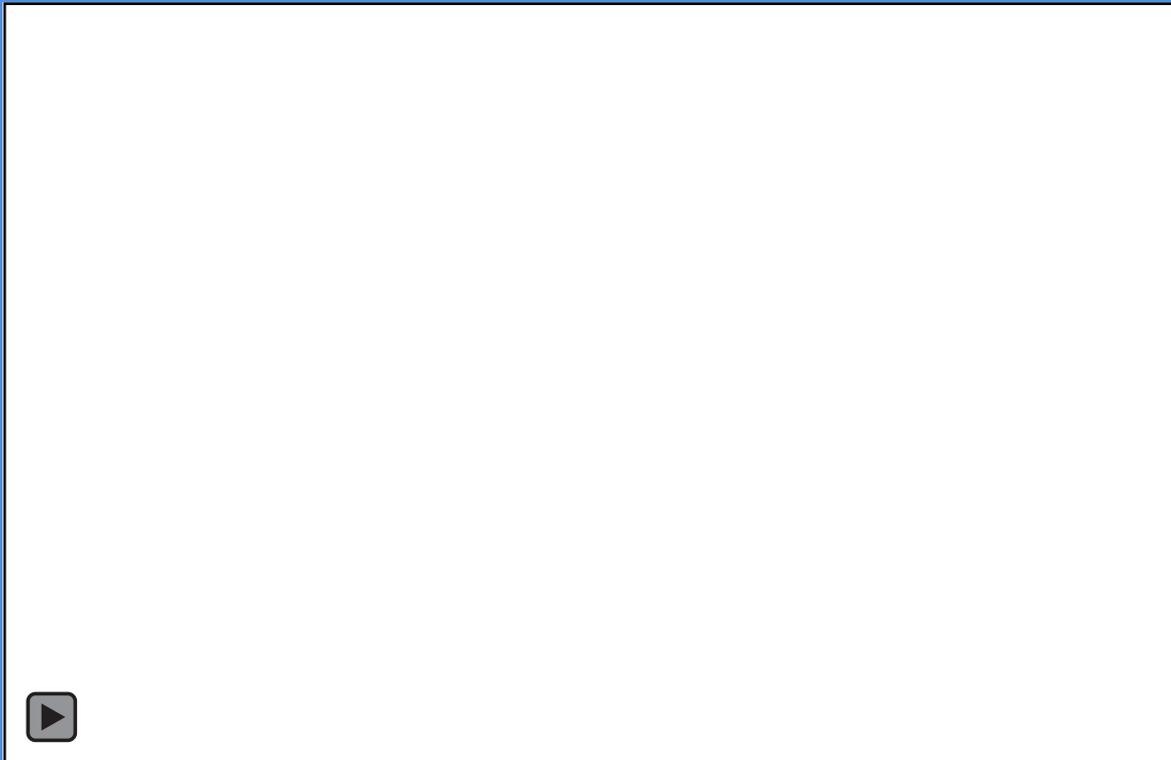
Bottom Right: ? Actually this sample as well as the one to the left of it were both send in to technical support and it turned out that in addition to tough conditions existing on site, there were also some flaws in the customers' collection methodology.



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?

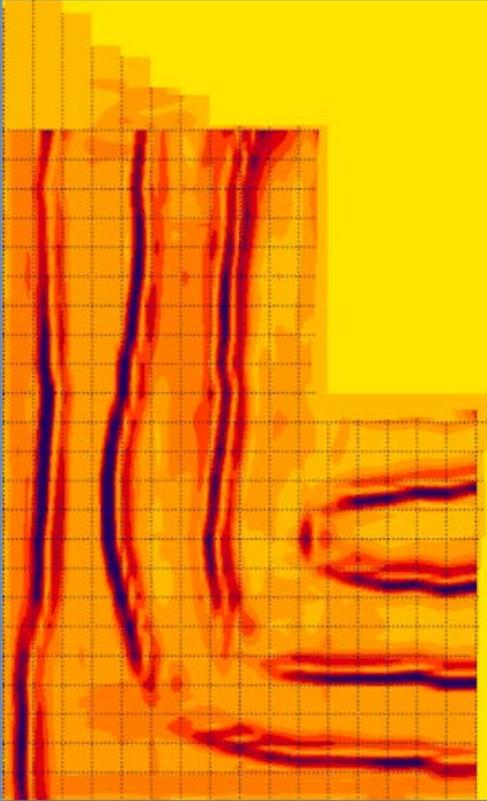
Just like with cross sections, automatic interpretation is the holy grail, but very little progress has actually been made in industry or academia. There have been some claims made to the contrary, but the results just don't live up to the claims.

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



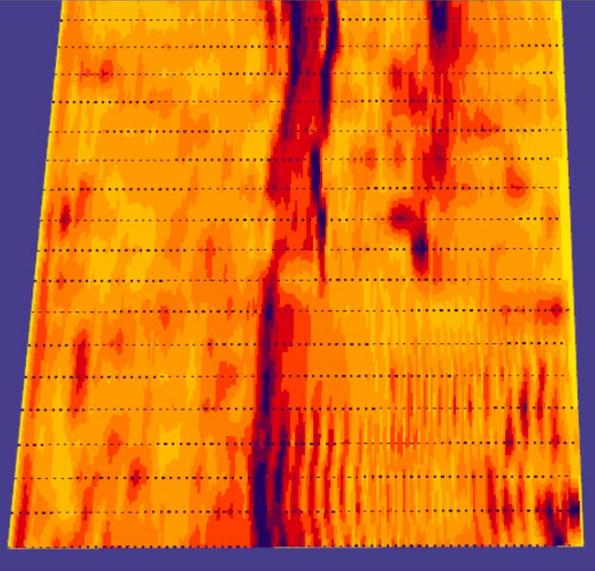
Left: original data

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.

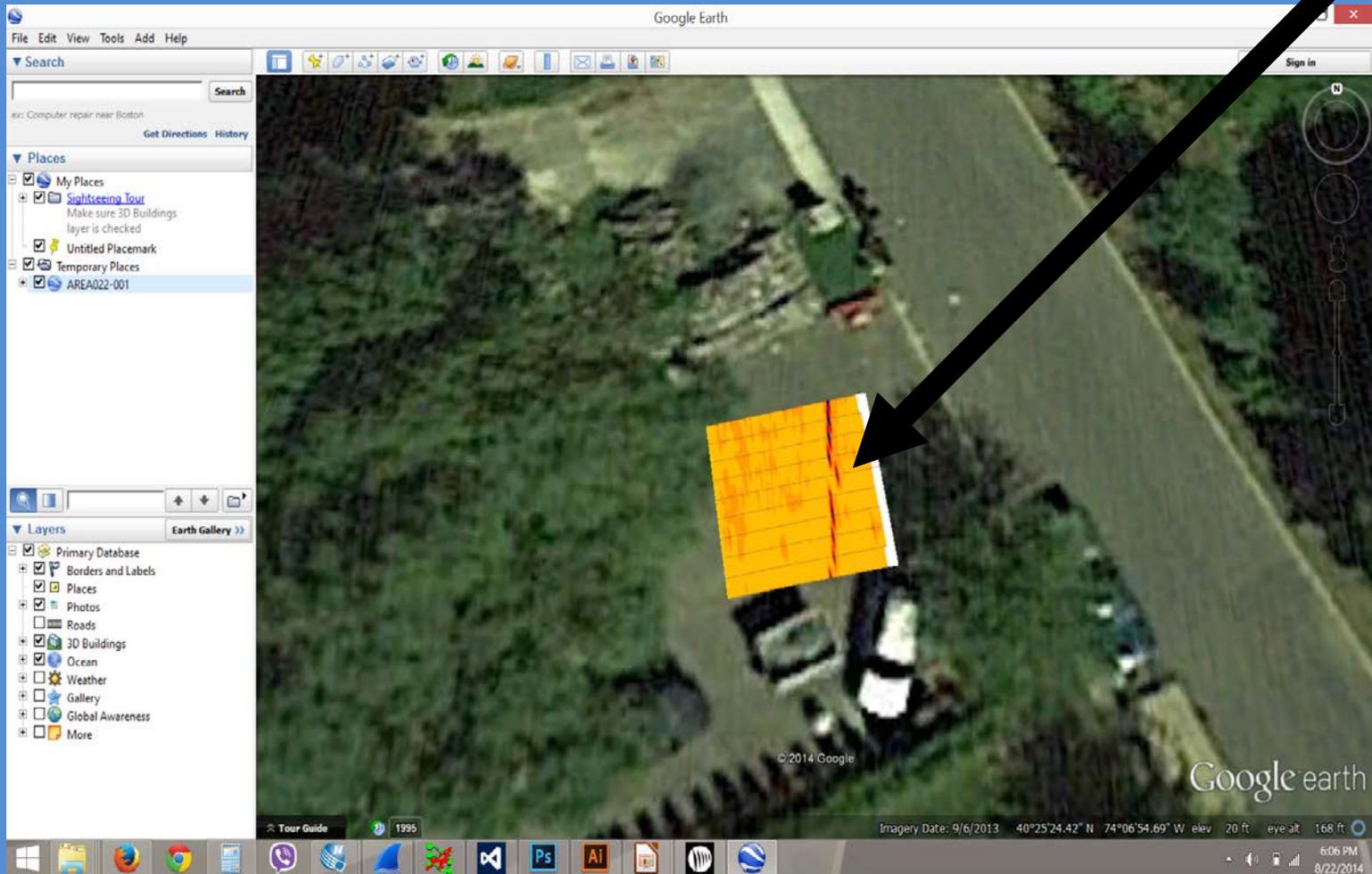
Note 2: The human reviewed the as-built which indicated 3 pipes.

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.





USRADAR INC.

SUBSURFACE IMAGING SYSTEMS

Thank You

Ron LaBarca

US Radar Inc

Matawan, NJ, 07747

732-566-2013

ron@usradar.com

www.usradar.com