Concrete Scanner

User Manual

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1 FCC Class A Compliance and Usage Limitations

This device complies with Part 15 Subpart B and Subpart F of the FCC Rules. Operation is subject to the following two conditions: (1) the device may not cause harmful interference, and (2) this device must accept any interference received including interference that may cause undesired operation.

FCC ID: 2AP78-CS2 and contains RF Module FCC ID: Z64-WL18DBMOD.

Warning: Changes or modifications to this unit not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

According to the FCC Rules Part 15 Subpart F, this device has several requirements and limitations for use. Specifically:

15.509:

(a) The UWB bandwidth of an imaging system operating under the provisions of this section must be below 10.6 GHz.

(b) Operation under the provisions of this section is limited to GPRs and wall imaging systems operated for purposes associated with law enforcement, fire fighting, emergency rescue, scientific research, commercial mining, or construction.

(1) Parties operating this equipment must be eligible for licensing under the provisions of part 90 of this chapter.

(2) The operation of imaging systems under this section requires coordination, as detailed in §15.525.

15.521:

(a) UWB devices may not be employed for the operation of toys. Operation onboard an aircraft, a ship or a satellite is prohibited.

15.525:

(a) UWB imaging systems require coordination through the FCC before the equipment may be used. The operator shall comply with any constraints on equipment usage resulting from this coordination.

1. **(b) The users of UWB imaging devices shall supply operational areas to the FCC Office of Engineering and Technology, which shall coordinate this information with the Federal Government through**

the National Telecommunications and Information Administration. The information provided by the UWB operator shall include the name, address and other pertinent contact information of the user, the desired geographical area(s) of operation, and the FCC ID number and other nomenclature of the UWB device. If the imaging device is intended to be used for mobile applications, the geographical area(s) of operation may be the state(s) or county(ies) in which the equipment will be operated. The operator of an imaging system used for fixed operation shall supply a specific geographical location or the address at which the equipment will be operated. This material shall be submitted to Frequency Coordination Branch, OET, Federal Communications Commission, 45 L St NE, Washington, D.C. 20554, Attn: UWB Coordination.

(c) The manufacturers, or their authorized sales agents, must inform purchasers and users of their systems of the requirement to undertake detailed coordination of operational areas with the FCC prior to the equipment being operated.

(d) Users of authorized, coordinated UWB systems may transfer them to other qualified users and to different locations upon coordination of change of ownership or location to the FCC and coordination with existing authorized operations.

(e) The FCC/NTIA coordination report shall identify those geographical areas within which the operation of an imaging system requires additional coordination or within which the operation of an imaging system is prohibited. If additional coordination is required for operation within specific geographical areas, a local coordination contact will be provided. Except for operation within these designated areas, once the information requested on the UWB imaging system is submitted to the FCC no additional coordination with the FCC is required provided the reported areas of operation do not change. If the area of operation changes, updated information shall be submitted to the FCC following the procedure in paragraph (b) of this section.

(f) The coordination of routine UWB operations shall not take longer than 15 business days from the receipt of the coordination request by NTIA. Special temporary operations may be handled with an expedited turn-around time when circumstances warrant. The operation of UWB systems in emergency situations involving the safety of life or property may occur without coordination provided a notification procedure, similar to that contained in §2.405(a) through (e) of this chapter, is followed by the UWB equipment user.

2 IC Compliance and Usage Limitations

This device complies with Canadian RSS-220, RSS-GEN and ICES-003. Operation is subject to the following two conditions: (1) the device may not cause harmful interference, and (2) this device must accept any interference received including interference that may cause undesired operation.

IC: 24708-CS2 and contains RF Module IC: 451I-WL18DBMOD.

According to the RSS-220, Issue 1, Section 6.2, this device has several requirements and limitations for use. Specifically:

(a)This Ground Penetrating Radar Device shall be operated only when in contact with or within 1m of the ground.

(b) This Ground Penetrating Radar Device shall be operated only by law enforcement agencies, scientific research institutes, commercial mining companies, construction companies, and emergency rescue or firefighting organizations.

(c) This In-wall Radar Imaging Device shall be operated where the device is directed at the wall and in contact with or within 20 cm of the wall surface.

(d)This In-wall Radar Imaging Device shall be operated only by law enforcement agencies, scientific research institutes, commercial mining companies, construction companies, and emergency rescue or firefighting organizations.

(e) This device complies with Industry Canada licence-exempt RSS standard(s). Operation is Subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired Operation of the device.

Cet appareil est conforme aux normes canadiennes RSS-220, RSS-GEN et ICES-003. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

IC: 2AP78-CS2 et contient le module RF IC: 451I-WL18DBMOD.

Selon le RSS-220, Issue 1, Section 6.2, cet appareil a plusieurs exigences et limitations d’utilisation. Plus précisément:

(a) Ce dispositif radar à pénétration du sol ne doit être utilisé qu'en contact avec le sol ou à au plus 1 m du sol.

(b) Ce dispositif radar à pénétration du sol ne doit être utilisé que par des organismes d’application de la loi, des établissements de recherche scientifique, des sociétés minières

commerciales, des entreprises de construction, et des organismes d'intervention d'urgence ou de lutte contre les incendies.

(c) Ce dispositif d'imagerie radar intramur doit être utilisé lorsqu'il est orienté vers le mur et en contact avec la surface du mur ou à au plus 20 cm de cette surface.

(d) Ce dispositif d'imagerie radar intramur ne doit être utilisé que par des organismes d'application de la loi, des établissements de recherche scientifique, des sociétés minières commerciales, des entreprises de construction, et des organismes d'intervention d'urgence ou de lutte contre les incendies.

(e) Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

3 Introduction

3.1 Overview

Figure 1: GPR Concrete Scanner without (left) and with (right) removable truck.

The GPR Concrete Scanner (Figure 1) locates objects that are embedded in concrete such as rebar, pipes, and conduits, measures concrete thickness, and can locate defects in concrete such as voids. When used with Surveyor Pro software for Windows (on an optional tablet PC) produces simple cross sections, depth slice images, or 3D images of the concrete structure. For simpler assessments, the scanner can also be used on Android and iOS smartphone or tablet using Surveyor Mobile (available free at the customary application marketplaces, see https://app.esscloud.net). The system includes a scanner unit with integrated radar, odometer, and power line detector. The removable truck makes floor scanning easier but can be removed to reduce weight when used on walls. An optional handle extension is available for scanning hard to reach places. The Concrete Scanner's cable-less design increases reliability and ease of use.

The system consists of the following components:

1. GPR Concrete Scanner
2. Removable Truck
3. Two Removable Batteries
4. Battery Charger
5. Extension Handle
6. Windows Tablet Computer (optional)

4 Operation

This section provides operating instructions for conducting surveys, generating reports, and recharging the batteries. Before starting a survey, determine the area to be surveyed and how it will be covered. Typically, there are two types of surveys: single line for producing a cross section view, or multi-line for producing a 3D view. The concrete surface must be clean and dry.

4.1 Hardware Assembly

During normal storage and transportation, the Concrete Scanner is packed in its shipping case. Proceed as follows to assemble the unit for surveying:

1. Open the battery door by squeezing the two tabs on either side of the rear of the handle.
2. Insert the battery and close the battery door, ensuring that both latches click.
3. If the extension handle will be used, remove the three pieces of the extension handle from the shipping case: the handlebar, the telescoping tube, and the scanner clamp. Mount the scanner clamp to the scanner, then attach the telescoping tube, and finally attach the handlebar. Adjust the telescoping tube as desired.
4. For single line scans use Surveyor Mobile on an Android or iOS tablet. Alternatively for multi-line or three-dimensional surveys, use Surveyor Pro on Windows™ tablet computer. The tablet or smartphone can be arranged in one of four modes while surveying for easy viewing (see Figure 2):
    A. Floor stand. Insert the extension handle into the socket of the shipping case and then mount the tablet onto the handlebar.
    B. Wrist-mounted smartphone.
    C. Extension handle. Attach the extension handle to the scanner and then the tablet to the handlebar.
    D. Tablet with kickstand on bench or table.

    For most surveys, the use of the kick stand or floor stand is recommended.

Figure 2: Different smart phone and tablet setups can be used for different survey types: A) Extension handle with tablet on floor stand, B) wrist-mounted smartphone, C) Extension-handle mounted tablet, D) Extension handle.

4.2 Surveyor Mobile Software Overview

The *Surveyor Mobile* is a native mobile application that runs on *Android*™ or *iOS*™, and supports both the GPS Base Station and the GPR Concrete Scanner. To install this app, scan the QR code printed on your ESS device, or visit the following address on your mobile device: https://app.esscloud.net. Consult the ESS *Surveyor Mobile* manual for more detailed information on use with the GPR Concrete Scanner (touch the App Manual button at the bottom of the app's green welcome screen).

Table 3. Surveyor Mobile vs. Surveyor Pro

Feature	Surveyor Mobile	Surveyor Pro
Requires Android or iOS	Yes	No
Requires Windows Tablet and Software Installation	No	Yes
Collects Single Line Survey	Yes	Yes
Review Previously Collected Data	No	Yes
Collects Multiple Freeform Lines or Grid	No	Yes
Export Data to ESSential Underground	No	Yes

The *Surveyor Mobile* supports the GPR Concrete Scanner with a limited set of capabilities, use *Surveyor Pro* on a Windows tablet to access all features. The features supported by each of these apps is summarized in Table 3.

To connect the *Surveyor Mobile* to a GPR Concrete Scanner, first make sure the the GPR unit has been powered on for at least 20 seconds. To connect for the first time: Under 'Add Device Using' panel select 'QR Code' and scan the QR code on the back of your GPR Concrete Scanner.

If you are unable to scan the QR code, under 'Add Device Using' touch 'Serial Number' and enter the serial number manually (see Figure 8). On *Android*™ devices, the WiFi signal of your GPR Concrete Scanner may cause the device to be added automatically. To connect to the same device again, just touch Connect under its serial number. (You can connect to a scanner, even if it does not indicate it is "Detected Near You".)

Figure : Connecting *Surveyor Mobile* to your GPR.

Once connected the display will automatically be locked to landscape mode. Move your GPR device forward and the canvas will paint in from left to right with GPR data. A typical scan is shown in Figure 9 where rebar is visible as hyperbolic arcs (hump-shaped) in the radar scan. The scale on top of the plot indicates the distance along the surface in feet or meters, and the vertical scale represents depth of the subsurface object.

The application menu is accessed using the three parallel lines in the top left corner or by swiping the left edge of the screen. Many options are accessible by scrolling vertically.

Figure : A GPR scan line on *Surveyor Mobile*. The red line plot indicates the detected magnetic signal of an electrical power line.

- The horizontal and vertical scales and zoom factors of the GPR scan can be adjusted.
- The scan automatically scrolls horizontally, but its maximum length is limited. Use the CLEAR & RESTART button to re-zero your position, or use the *Surveyor Pro* on your Windows computer for longer scans.
- Use the PAUSE button to prevent unwanted scrolling. No data is collected while paused.
- Some operations, such as marking a hyperbola, automatically pause the scan. If the updates are paused the PAUSE button will change to a blinking yellow RESUME button. Touch the RESUME button to resume your scan.
- The red line plot indicates the relative magnetic signal which is typically generated by alternating current electrical power wiring. This is a relative indication only. Note that certain types of cabling and conduit will make this signal difficult or impossible to detect, and wiring which is not carrying current is inherently undetectable by this method. Note that the sensor is sensitive to both buried and overhead lines.

Figure : Measuring a hyperbolic reflection pattern for depth calibration of a GPR scan.

The speed of radar waves in the subsurface is different for different materials, and it is therefore necessary to calibrate the depth scale. This is typically accomplished by measuring the width of the hyperbolic reflection patterns. To calibrate depth, open the application menu and select ‘Mark Hyperbola’ button to fit a scanned hyperbola (see Figure 10). Use the displayed controls to match the dashed line to the hyperbolic reflection pattern.

4.3 Surveyor Pro Software Overview

Surveyor Pro has many more features than Surveyor Mobile, but requires a Windows PC. After opening the Surveyor Pro acquisition program, the *Home* tab will be displayed (see Figure 3). Here the user will specify project specific information and conduct a new survey, or open previously collected data to replay.

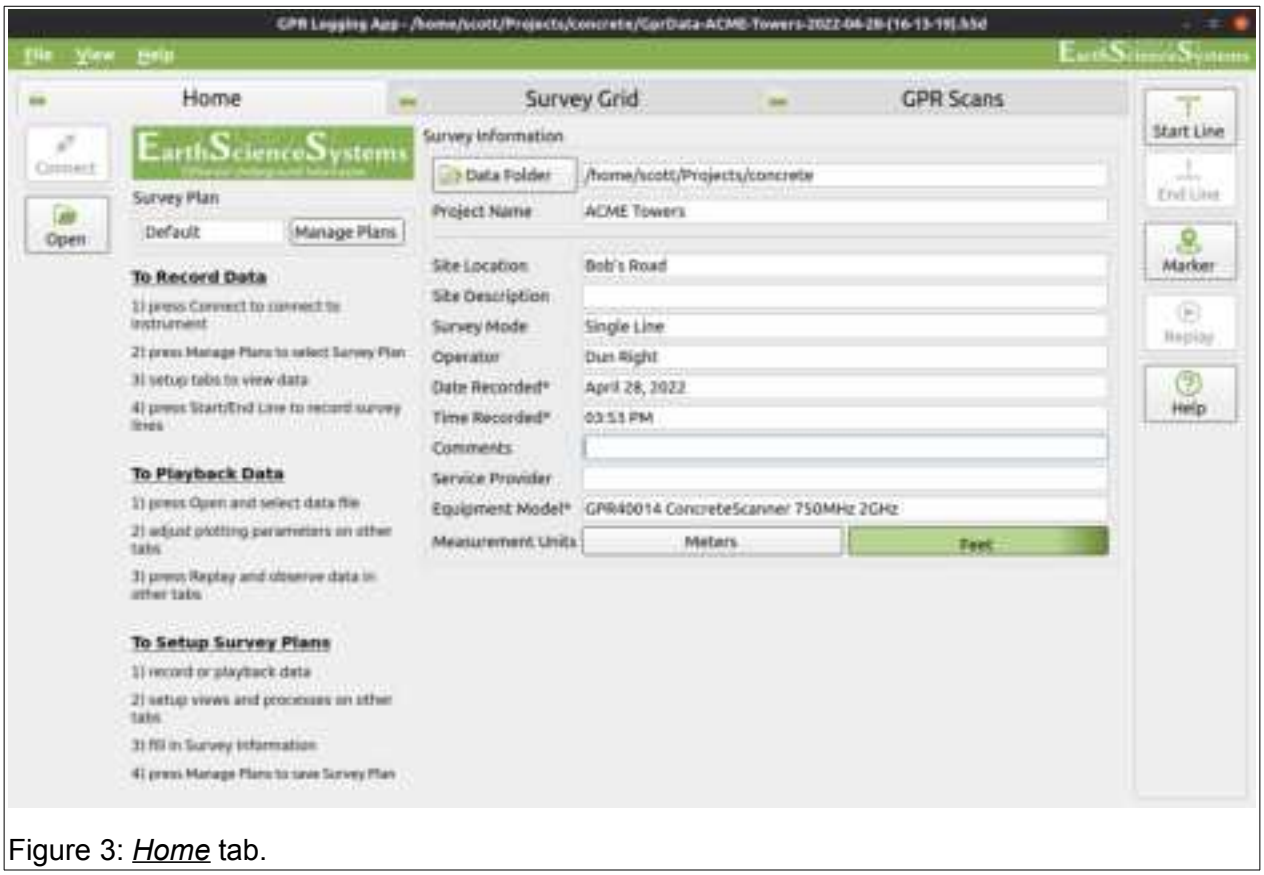

Figure 3: *Home* tab.

4.3.1 Home Tab

Before beginning a survey, it is important to capture information about the job site on the *Home Tab*. The information entered into this page will be listed in any reports that will be generated by the software. To type into an edit box, tap on the box to place the cursor in the box and bring up the keyboard.

1. The *Connect* button on the *Home* tab can be used to connect to and begin receiving data from the instrument. Before clicking the *Connect* button, first ensure that the tablet running the Surveyor Pro is connected to the WiFi access point of the Concrete Scanner.

2. The *Manage Plans* button can be used to open or save a named survey plan for the job, including data file location, survey grid, and plot settings. It is especially useful to setup configurations in advance when repeatedly conducting similar jobs. Within the *Manage* dialog, use *Open* to open an existing survey plan, *Save* to update an existing survey plan, *Delete* to delete a survey plan, and *Save As* to create a new survey plan. When the user presses *Done*, the current settings are saved to the selected survey plan name. For repeat jobs, it is suggested that the desired settings are copied to the Default plan, which is then used as the working plan that receives small changes as needed. The Default plan cannot be deleted.
3. *Data Folder:* Select a folder for storing data. All recorded data will be placed in the specified folder using an automated time-date file naming convention.
4. *Project Name*: All output files will have the project name in the filename.
5. *Job Site Information:* Enter the *Site Location*, *Site Description*, *Operator*, *Survey Mode*, *Comments*, and *Service Provider*. The *Date Recorded, Time Recorded,* and *Equipment Model* fields will be updated automatically after connecting to the instrument.
6. *Measurement Units:* Select the distance units (*Meters* or *Feet*).

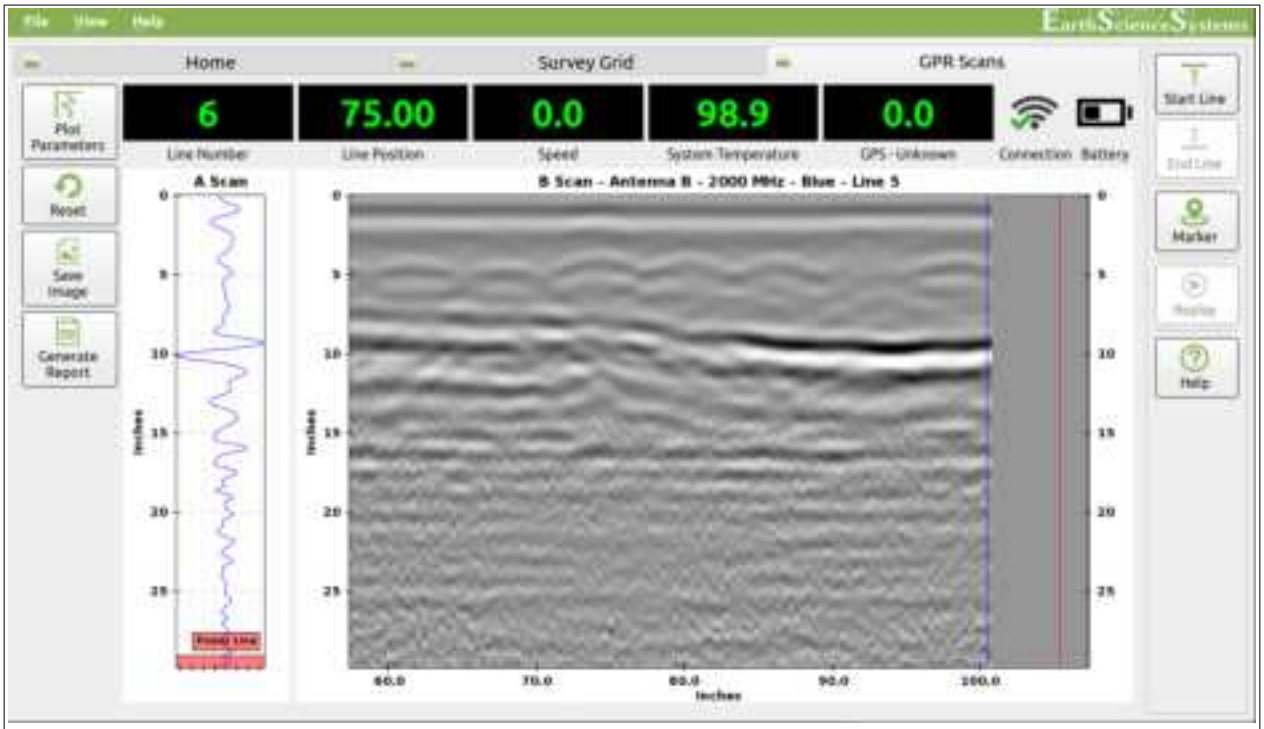

Figure 4: *GPR Scans* tab.

4.3.2 GPR Scans Tab

This tab is displayed (see Figure 4) by clicking the *GPR Scans* tab. The *GPR Scans* tab displays A-scan and B-scan plots that are useful for viewing GPR waveforms and ensuring

proper system operation. Touch and drag to pan. Pinch with two fingers inward or outward to zoom out or in, respectively. Press the *Reset* button to return to the default view. The plot parameters can be changed by pressing the *Plot Parameters* button (see Figure 5). For most users, the default settings will be sufficient. For those interested, the dialog functions are described below:

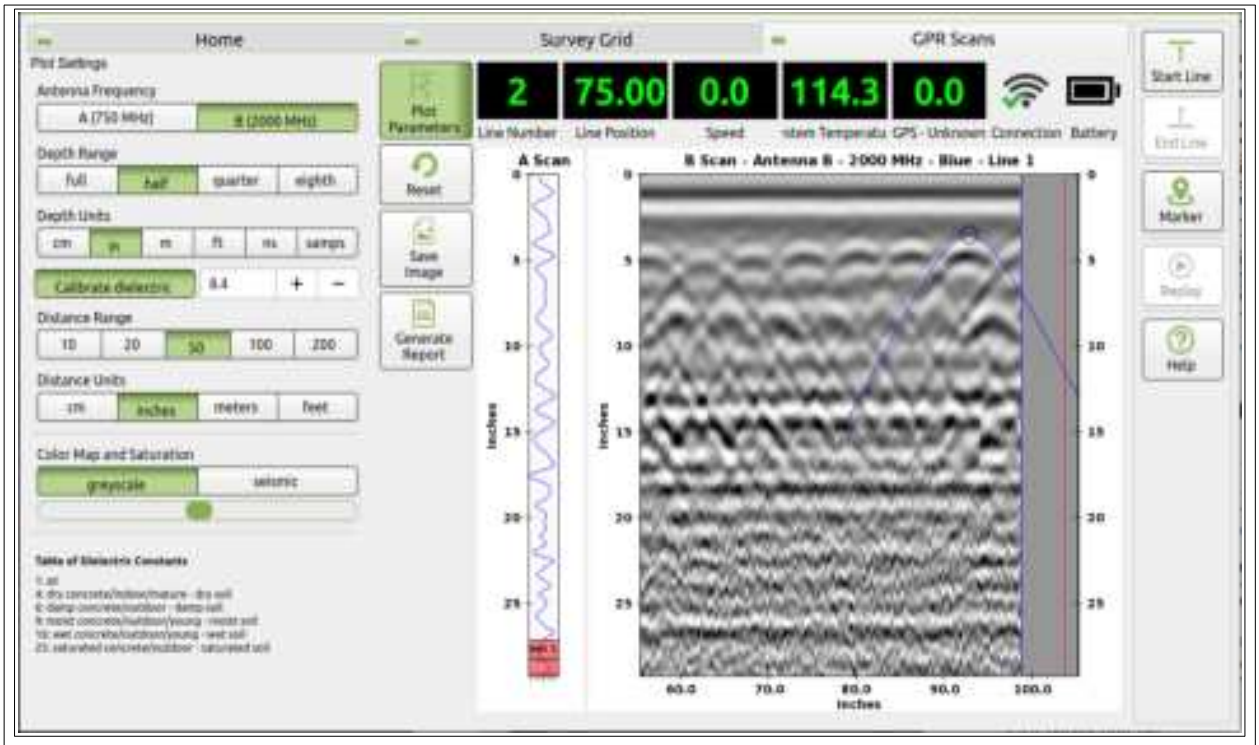

Figure 5: Plot settings dock. After clicking *Calibrate dielectric*, touch the top of a hyperbola. Then touch + or – until blue hyperbola matches the reflected radar arrivals on the screen.

1. *Depth Units:* Select the units for the vertical scale on the B-scan. The most basic units are sample number (*samps*). Sample number multiplied by the digitizer sample period gives sample time (*ns*). Sample time multiplied by the medium velocity gives distance (*cm*, *in*, *m*, *ft*).
2. *Depth range:* Users can opt to display the *full* range, *half* range, *quarter* range, or *eighth* range depending upon range of interest.
3. *Dielectric (velocity) of medium:* The velocity of EM waves must be known in order to convert time of flight to depth. The velocity is determined by the dielectric constant of the material through which the wave is traveling as shown by this equation: $v = c/\sqrt{\varepsilon}$ (v is the EM wave velocity, c is the speed of light in a vacuum, and ε is the dielectric constant of the medium). To calibrate: click *Calibrate dielectric*, then touch the crest of a hyperbola in the image. A hyperbolic line will appear showing the predicted arrival curve. Click the "+" or "-" buttons to adjust the curve (and dielectric) until it matches your hyperbola (Figure 5). Here are some dielectric constants for common materials:

Air	$\varepsilon = 1$
Dry concrete/indoor/mature - Dry soil	$\varepsilon = 4$
Damp concrete/outdoor - Damp soil	$\varepsilon = 6.5$
Moist concrete/outdoor/young - Moist soil	$\varepsilon = 9$
Wet concrete/outdoor/young - Wet soil	$\varepsilon = 16$
Saturated concrete/outdoor - Saturated soil	$\varepsilon = 25$

5. *Distance Range:* Select the horizontal range of the B-scan in distance units (*10*, *20*, *50*, *100*, *200*).
6. Distance Units: Select *cm*, *inches*, *meters*, or *feet*.
7. Color Map and Saturation: Select either *greyscale* or *seismic* for the type of color map. Move the slider left or right to decrease or increase the display gain, respectively.

The *GPR4 Scans* tab also has buttons for saving the B-scan image and generating a short report. The image can be saved as a PNG, BMP, or JPG file. The report will be saved as a PDF file, and will contain the survey metadata and the B-scan image.

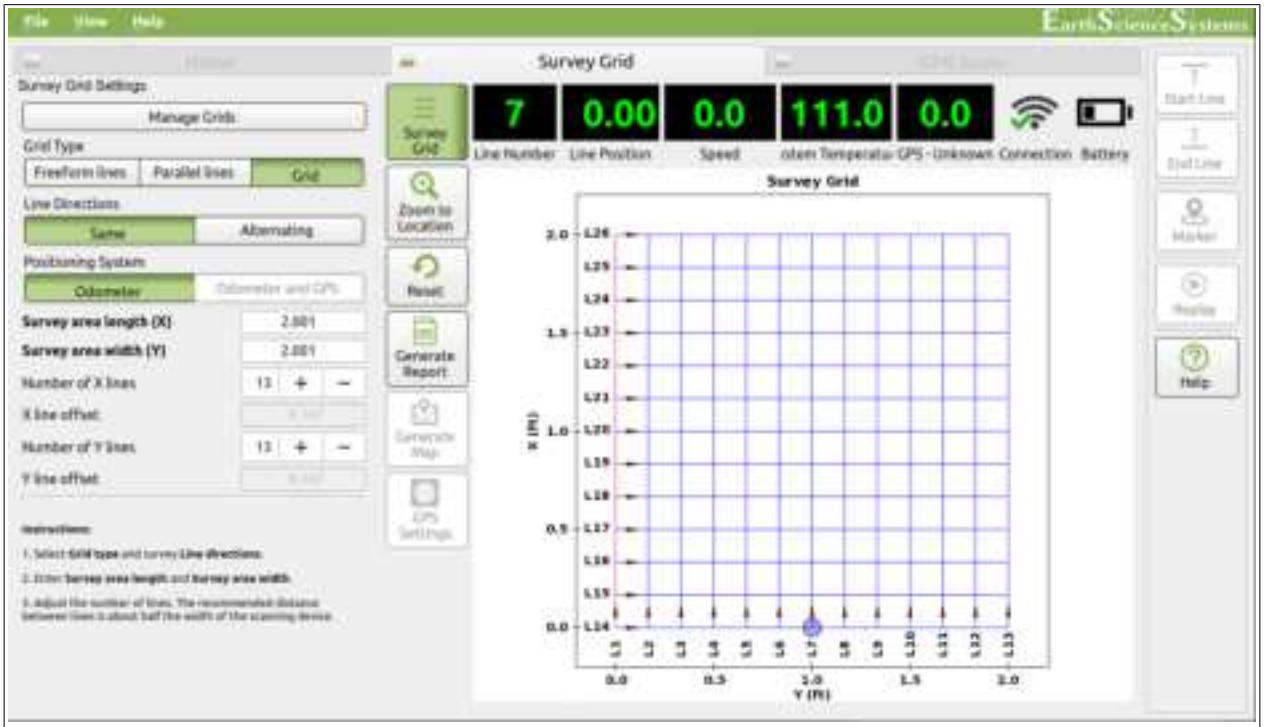

Figure 6: *Survey Grid* tab with open dock. Blue dot indicates current sensor position.

4.3.3 Survey Grid Tab

The *Survey Grid* tab shows how the linear traverses making up the survey will be arranged. These traverses are planned using the *Survey Grid* button and the dialog shown in Figure 6. The survey grid is defined with the x-axis in the direction of Line 1 and the y-axis to the right of Line 1. On roads, Line 1 is typically oriented in the direction of increasing or

decreasing station number. To type into dialog field, click on the field to place the cursor and bring up the keyboard.

1. *Line Number:* The *Line Number* shown on the top right of the screen increments automatically during the survey. To manually change the line number, touch the *Line Number* to bring up the line number editor.
2. *Battery:* The battery symbol on the top left side of the display shows the battery status for the scanner. Touch the battery symbol to show more detailed information.
3. *Grid type:* Select either *Freeform lines*, *Parallel lines*, or *Grid*. *Freeform lines* allow for single, curved recording lines. Parallel lines are meant for straight recordings with consistent spacing between lines. *Grid* is essentially two sets of *Parallel Lines* recorded orthogonally to each other.
4. *Line Directions:* Select either *Same* or *Alternating* (*Alternating* can require less walking for large *Grid* and *Parallel lines* surveys with the extension handle).
5. *Positioning System:* Only *Odometer* is available for the Concrete Scanner.
6. *Survey area length (X)* and *Survey area width (Y):* These parameters specify the dimensions of the survey grid or length of line for *Freeform lines*.
7. *Number of X lines:* This parameter specifies the number of lines in the y-direction (it is recommended to adjust this until the *X line offset* displays about 2 inches or 5 cm).
8. *Number of Y lines:* This parameter specifies the number of lines in the x-direction (it is recommended to adjust this until the *Y line offset* displays about 2 inches or 5 cm).
9. *Manage Grids:* The *Open* button can be used to recall the dialog settings from a named configuration. This is useful when conducting a series of jobs with a similar layout. With the desired configuration highlighted, click *Open* to recall the existing configuration. Click *Save* to save settings to the highlighted name Click *Delete* to delete the highlighted name. Click *Save As* and provide a name to store the current settings to a new configuration. *Done* closes the dialog. For repeat jobs, it is suggested that the desired settings are copied to the Default template, which is then used as the working configuration that receives small changes as needed. The Default template cannot be deleted.

The *Survey Grid* tab also includes the *GPS Settings* button  which is not used with the Concrete Scanner because it does not contain a GPS sensor.

4.4 Conduct a Single Line Survey

A single line surveys is a quick method that is usually used to find where a small number of subsurface conduits intersects the survey line. For best results, run the scanner in a line perpendicular to the trajectory of the object of interest. To conduct a survey, proceed as follows:

1. Make sure that the scan head batteries and tablet PC batteries have been charged (see section on charging the batteries).
2. Turn on the power to the sensor unit. The power switch should glow with a green light.

3. Boot up the tablet computer and log in (default password is 'essential').
4. Connect to the sensor unit via WiFi. On the task bar, press the WiFi network icon  , then select the network connection for the Concrete Scanner. The name of the connection will be the serial number of the scanner (e.g., GPR40123). It will take 30-60 seconds after the sensor box has been powered up for the network to appear on the tablet. Select the network connection for the scanner and wait for it to connect. Windows will ask if you would like to connect automatically. If you enable automatic connection, then this step can be skipped for future surveys.
5. Start the data acquisition program by double tapping *Surveyor Pro* icon on the desktop. Press the *Connect* button to connect to the scanner. After a few seconds the program will display the *GPR Scans* tab and will start updating with data (see Figure 4). The green light on the scanner's power button will flash slowly when it is connected to the acquisition program on the tablet computer.
6. Enter the jobsite information into the *Home* tab (see Figure 3). Then click *Manage Plans* to save this information if desired.
7. The GPR data can be recorded for later playback and examination if desired. When locating intersecting conduits, some users may choose not to record the data. To manage data storage, click *Data Folder* and specify an output folder.
8. Move to the *Survey Grid* tab and press the *Survey Grid* button  . Insure that the survey area length is long enough to conduct the survey, then press the *Survey Grid* button again to close the dock. This step can be skipped if a job site configuration was loaded with the desired survey grid.
9. Move the scanner to the start position of the line. To start recording, press the *Start line* button  . This action can also be accomplished by pressing the rocker button on the radar unit ***up*** momentarily. Each time this button is pressed, the system runs through a line initialization sequence which tasks a few seconds. When the user hears an audible beep from the tablet, the initialization sequence has completed. Move the scanner along the survey line to conduct the survey.
10. Continue moving the scanner along the survey line until the it moves beyond the conduit of interest. Roll the scanner backwards on the line until the scanner is positioned directly over the conduit and mark the position on the concrete surface with a marker. While recording data, a marked fiducial can be placed in the data file by pressing the  icon.
11. When finished with the survey line, press the *End line* button  to stop recording. This action can also be accomplished by pressing the rocker switch on the scanner ***down*** momentarily.
12. If no further surveys are to be conducted, power down the scanner. Disassemble the scanner and return all components to the shipping case.

4.5 Conduct a 3D Survey

Users usually conduct 3D scans when depth slices or 3D views of the subsurface are desired. To conduct a 3D survey, proceed as follows.

1. Make sure that the scanner batteries and tablet PC batteries have been charged (see section on charging the batteries).
2. Turn on the power to the sensor unit. The power switch should glow with a green light.
3. Boot up the tablet computer and log in (default password is 'essential').
4. Connect to the sensor unit via WiFi. On the task bar, press the WiFi network icon  , then select the network connection for the Concrete Scanner. The name of the connection will be the serial number of the scanner (e.g., GPR40123). It will take 30-60 seconds after the sensor box has been powered up for the network to appear on the tablet. Select the network connection for the scanner and wait for it to connect. Windows will ask if you would like to connect automatically. If you enable automatic connection, then this step can be skipped for future surveys.
5. Start the data acquisition program by double tapping the *Surveyor Pro* icon on the desktop. Press the *Connect* button to connect to the scanner. After a few seconds the program will display the *GPR Scans* tab and will start updating with data (see Figure 4). The green light on the scanner's power button will flash slowly when it is connected to the acquisition program on the tablet computer.
6. Enter the job site information into the *Home* tab (see Figure 3). Then click *Manage Plans* to save this information if desired. Lastly, specify a data storage directory by clicking the *Data Folder* button.
7. Move to the *Survey Grid* tab, press the *Survey Grid* button  , then press *Manage Grids* to select the desired survey grid. Survey grid presets are available for the scan grid mats available from ESS (see Figure 1). Alternatively, use the *Survey Grid* settings dock to enter the parameters for a custom survey grid and save them. Press the *Survey Grid* button when finish editing to close the dock. This step can be skipped if a job site configuration was loaded with the desired survey grid.
8. Move the scanner to the start position of the first line. To start recording, press the *Start line* button  (wait for the beep) and then traverse the line with the scanner. The *Start line* action can also be accomplished by pressing the rocker button on the radar unit ***up*** momentarily. When the scanner reaches the end of the line it will automatically stop the current line and setup for the next line. To stop recording before reaching the end of the line, press the *End line* button  or press the rocker button on the radar unit ***down*** momentarily.
9. Repeat step 8 until all of the survey lines in the grid have been scanned. While scanning a line, users can place markers in the data file when the line traverses a point of interest (usually an obvious surface feature) by pressing the  icon.
10. If no further surveys are to be conducted, power down the sensor. Disassemble the scanner and return all components to the shipping case.

4.6 Replaying Data

The ESS Concrete Scanner allows replaying data so that plots can be re-examined and new reports can be generated. To replay data, follow the instructions below.

1. Start the data acquisition program by double tapping the *Surveyor Pro* icon on the desktop.
2. Once the acquisition program loads, press the *Open* button on the *Home* tab and then select the file(s) to replay.
3. When prompted to update plot settings, press the *GPR Scans* tab then set the desired plot parameters.
4. Press the Replay button  on either the *GPR Scans* or *Survey Grid* tabs. The plots will update as the data replays. When the replay is completed, users can generate reports and maps as desired.

4.7 Generating Maps and Reports

Once the data has replayed, reports can be generated.

- To save an image of the either the B-scan, press the  icon. Select desired image file type (PNG, BMP, or JPG) and file name.
- To generate a brief PDF report press the  button and select the desired file name. The report contains the job information metadata and images of the GPR scans.

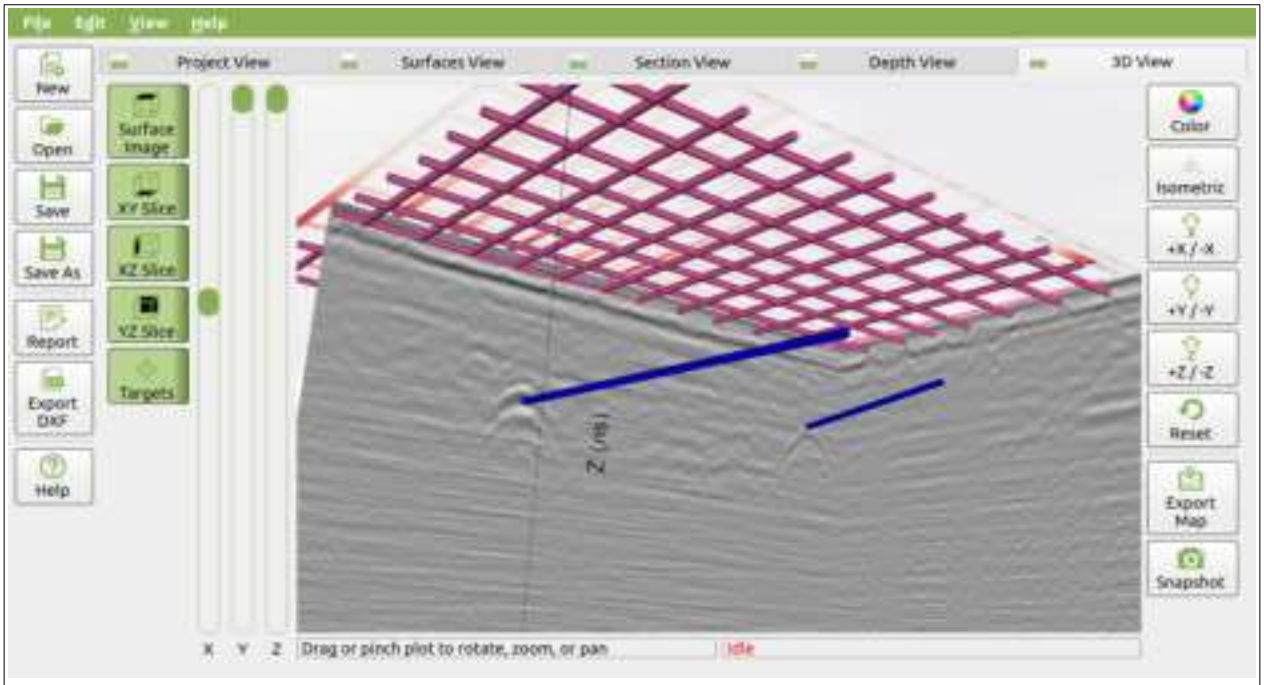

Figure 7: 3D data view from ESSential Underground.

4.8 Advanced Data Processing, Depth Slices, and 3D Views

The *Surveyor Pro* does not have the capabilities to generate depth slices or 3D views of the subsurface. To generate these views, use the companion program *ESSentialUnderground* that is distributed with the system (see Figure 7). For more information, see the ESSential Underground manual.

4.9 Charging the Batteries

The GPR is supplied with two rechargeable batteries that provide sufficient power for operation over a full day. Additionally, the tablet (if so equipped) contains a battery that will provide 5-8 hours of continuous operation depending on screen brightness settings. The system is designed to be charged overnight so that all of the batteries are ready for use during the work day. To charge the batteries, follow these steps.

1. Switch off the scanner (Long press 3 seconds to turn off). Remove the battery from the scanner.
2. Place both scan head batteries onto the charger.
3. Connect the tablet charging brick cable to the tablet computer and connect to 120/200 VAC mains power.
4. All batteries should charge in 4-5 hours. The following are the LED Indications of the included charger:

LED Indications	
One time Red/Orange/Green	Self-test: Charger is ready for use.
Red/Green blinking	Battery recognition and initialization.
Orange blinking	The battery is currently being calibrated.
Orange light	The inserted battery is of the correct type and is currently being charged.
Green light	The battery is charged and can be removed for use.
Red blinking	The battery is too hot or too cold to be charged without damage. If the battery is too cold it will be charged as soon as it has warmed up sufficiently. If the battery is too hot it should be removed to cool down.
Red light	The battery is damaged or it is a conventional battery which cannot be recharged.

4.10 System Care, and Cleaning

The concrete scanner system kept clean and free of debris. The sensor unit can be cleaned with water and a mild detergent.

4.11 Remote Desktop Training Configuration

For training and demonstration purposes, the system can be configured so that the tablet's desktop can be shared to a remote office where a trainer or presenter is located. Since the tablet computer's internal WiFi is used to connect to the GPR system, a different means of connecting to the internet is needed to provide remote desktop sharing. This can be accomplished using an external WiFi dongle to connect to a local WiFi internet connection, or using the tablet's internal cellular data modem if so equipped. The instructions below use the external WiFi dongle which is supplied with all tablets purchased from ESS.

1. Identify a WiFi access point that is provided by you office or a tethered cellular phone. Insert the WiFi dongle into the USB port on the side of the tablet. On the task bar, press the WiFi network icon , then at the top of the menu select the WiFi2 adaptor and then select the proper WiFi internet connection. Network adaptor WiFi will be left to connect to the GPR system.
2. The trainer or presenter will call the equipment operator's office or cellular phone and ask for the screen sharing code from the operator. The equipment operator will start the AnyDesk application and then provide the remote support ID over the phone. The trainer or presenter can now see and use the tablet computer to demonstrate how to operate the system.
3. When the training session is complete, simply exit from the AnyDesk application and remove the WiFi dongle.

5 Theory

5.1 Theory of Operation

The concrete scanner uses ground penetrating radar (GPR) to characterize the surface beneath the sensing unit. The GPR sends a low-energy impulse of electromagnetic (EM) energy towards the surface. Some of this energy penetrates into the subsurface and some is reflected back towards the sensor unit. The amount of reflected energy depends on the contrast in dielectric constant and electrical conductivity of the soil and embedded objects. By measuring the travel time of these waves, the depth to the reflectors can be determined in a manner analogous to a fish finder. By moving the scanner over the surface and detecting objects beneath it, a 2D or 3D cross section of the subsurface can be obtained.

High frequency radar waves (i.e. 750 MHz) provide better spatial resolution than lower frequency radar waves, but they attenuate more quickly as they travel through the subsurface, resulting in a maximum object detection depth of about two feet. Lower frequency radar waves (i.e. 350 MHz) are able to penetrate more deeply (to about 20 feet) but do not provide subsurface images with as much detail.

6 Appendix

6.1 GPR Settings

Click *File*, *GPR Settings* to customize map and digitizer settings for the unit.

6.1.1 Map Settings

Map settings are not applicable to this product, as it does not have a GPS sensor.

6.1.2 GPR Settings: Simple

The default settings for the digitizer are sufficient for nearly all surveys. Advanced users may choose to change these settings (see Figure 8). To view or change the GPR settings, select (*File*, *GPR Settings*, *GPR Settings*).

- *Normal Investigation Depth*: This is the default and should work well for most surveys (512 samples).
- *Deep Investigation Depth*: Use this setting for deeper targets (1024 samples).
- *Advanced Settings*: Click here for even more control.

Figure 8: GPR Settings: Simple.

6.1.3 GPR Settings: Advanced

For fine tuning of the digitizer, adjust the following settings (See Figure 9).

- *Trace Sample Rate:* Select the desired number of traces per second. Using fewer traces per second gives a higher signal to noise ratio and increased depth of investigation. However fewer traces per second will result in fewer traces per foot (meter) at a given traverse speed.
- *Sample Rate:* Select the sample rate used for each A-scan. Normally a sample rate of 8 GHz is used for antennas with center frequencies less than 1 GHz, and 16 GHz is used for antennas with center frequencies greater than 1 GHz.
- *Num Samples:* Select the number of samples for each A-scan. A value of 512 samples will work for most situations. Note that using a large number of samples (1024 or more) may limit the *Trace Sample Rate*.
- *Channel A/B Holdoff:* The GPR digitizer has two channels: A and B. The holdoff time can be adjusted independently for each channel. The B channel can only be adjusted in 4 ns increments relative to the A channel. Normally, users will not need to change these values.

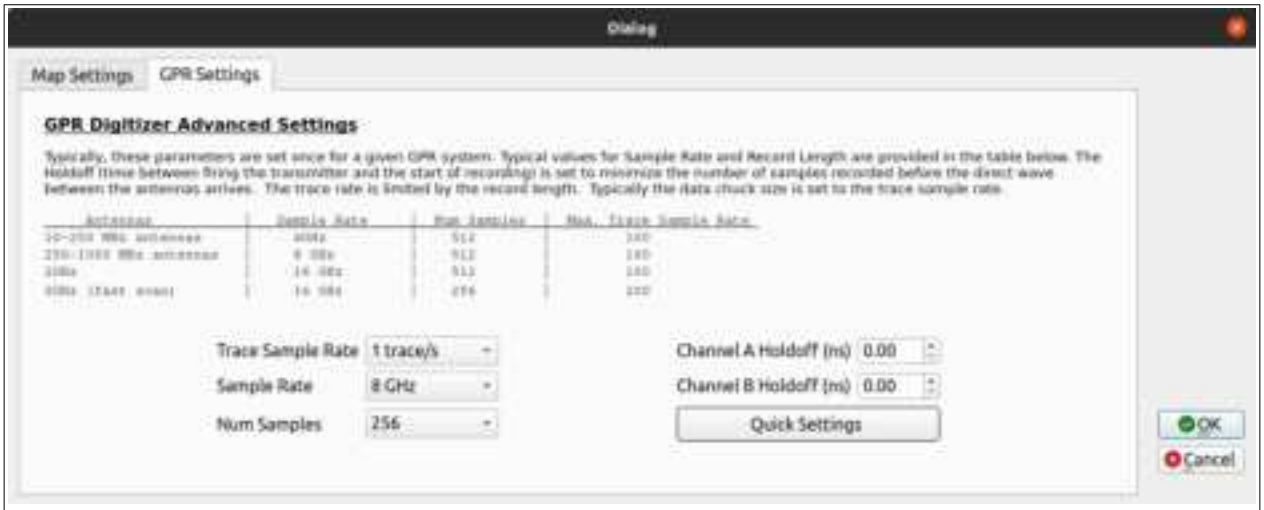

Figure 9: GPR Settings: Advanced.

6.2 Software Installation

If the tablet computer has not yet been setup for use with the Asphalt Pavement Scanner, proceed as follows. The thumb drive that was distributed with the system will be needed.

1. Most users will have tablets provided by ESS, in which case the software is already installed. To check for updates and install the updates, select *Help* and then *Check for Updates*. The software with check for all necessary updates and install them. The tablet must be connected to the internet.

2. For users installing software on computers not provided by ESS, use the following instructions. ESS software is currently compatible with Windows 10 and Windows 11 (For performance reasons Windows 10 is preferred).
3. Turn on the tablet, wait for it to boot up, and then log in.
4. Press and hold the task bar. Make sure the following options are checked:
    a) Show touch keyboard button.
    b) Show touchpad button.
5. Connect the thumb drive to the tablet's USB port.
6. Copy these files from the thumb drive to the desktop: *installEssPythonDistribution-x.x.x-(date).exe and installSurveyor Pro-x.x.x-(date).exe.*
7. Touch and hold the *installEssPythonDistribution-x.x.x-(date).exe* file on the desktop, then select *Open*. Follow the prompts to install this package.
8. Touch and hold the *installEssSurveyorPro-x.x.x-(date).exe* file on the desktop, then select *Open*. Follow the prompts to install this package.

6.3 Log File

The acquisition program writes a log file with all of the contents of the status panel. This file is overwritten each time the program runs. It can be useful to refer to this file to help diagnose problems. It is located in the user's home directory on this path:

\AppData\Local\Earth Science Systems\Surveyor Pro\scripts\log\Surveyor Pro.log.

6.4 Emissions

6.4.1 Health and Safety

ESS GPR systems emit electromagnetic radiation from the radar sensor, the WiFi adapter, and the Bluetooth adapter (if present). The electromagnetic radiation from ESS GPR radar sensors is many times less than that from cellular telephones. ESS GPR systems can be operated anywhere cellular telephones are permitted. The health and safety hazards posed by ESS GPR systems are less than those posed by cellular telephones.

6.5 Limited Product Warranty

Limited ESS Product Warranty. Subject to the provisions set forth below, Earth Science Systems, LLC ("ESS") represents and warrants (the "Limited Product Warranty") that all ESS goods, equipment or other ESS products (collectively, "ESS Products") sold by ESS or an authorized ESS reseller will materially conform to ESS specifications, will be free from defects in material and workmanship under normal use, and any ESS software included in the ESS Products is free from any defect, virus, trojan, worm, backdoor, or bug, for a period of one year from the date of initial sale by ESS or its authorized reseller to an end user or customer (an "End User").

1. ESS Product Warranty Limitations. This Limited Product Warranty does not apply to any third-party products sold by ESS or its authorized representatives; all third-party items are subject to the third-party's warranty and End User's exclusive remedy is against

such third-party. Further, the Limited Product Warranty does not apply to any ESS Product that is not functioning as intended or does not meet the provisions above due to: (a) abuse, misuse, neglect, negligence, accident, improper testing, improper installation, improper storage, improper handling, abnormal physical stress, abnormal environmental conditions or use contrary to any written instructions issued by ESS; (b) reconstruction, repair, or alteration by persons other than ESS or its authorized representative; or (c) any use with third-party products or hardware that have not been previously approved in writing by ESS.

2. Exclusive Remedy. All claims for breach of the Limited Product Warranty shall be made promptly after discovery. ESS's sole obligation, and End User's exclusive remedy, for any breach of the Limited Product Warranty, is limited to ESS repairing or replacing the ESS Products that are returned to ESS with shipping and insurance prepaid by End User, without alteration or further damage, and that, in ESS's judgment, were defective or became defective during normal use. A Return Material Authorization ("RMA") is needed for any return of the defective ESS Product. ESS is not responsible for damage that may occur during shipping due to improper packaging. Manufacturer will warranty replacement parts for 90 days. If ESS determines that there was no breach of the ESS Product Warranty, the End User assumes the entire cost of all necessary servicing, repair or correction.

3. Disclaimer of Warranties. Except as specified above, the ESS Product is provided "as is" without warranty of any kind, either expressed or implied, including, but not limited to, the use or result of use of the product in terms of correctness, accuracy, reliability, currentness or otherwise. The entire risk as to the results and performance of the ESS Product is assumed by the End User.

4. Limitation of Liability. IN NO EVENT SHALL ESS OR ITS REPRESENTATIVE BE LIABLE TO END USER, ITS AGENTS, SERVANTS, EMPLOYEE OR REPRESENTATIVES FOR ANY INDIRECT, PUNITIVE, SPECIAL, EXEMPLARY, INCIDENTAL, CONSEQUENTIAL OR OTHER DAMAGES OF ANY TYPE OR KIND (INCLUDING LOSS OF REVENUE, PROFITS, USE OR OTHER ECONOMIC ADVANTAGE) ARISING OUT OF, OR IN ANY WAY CONNECTED WITH THE ESS PRODUCT, INCLUDING BUT NOT LIMITED TO THE USE OR INABILITY TO USE THE ESS PRODUCT, OR FOR ANY INTERRUPTION IN WORK SCHEDULE, INACCURACY, ERROR OR OMISSION, REGARDLESS OF CAUSE, EVEN IF ESS HAS BEEN PREVIOUSLY ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. FURTHER, ESS'S ENTIRE LIABILITY FOR ANY CLAIM OR CAUSE OF ACTION ARISING FROM OR IN CONNECTION WITH any breach of the limited product warranty SHALL NOT EXCEED AN AMOUNT EQUAL TO THE TOTAL AMOUNT OF THE PURCHASE PRICE ACTUALLY PAID BY END USER FORM ESS O ITS AUTHORIZED RESELLERS.

5. Indemnification. Except for the exclusive remedy set forth above relating to the Limited Product Warranty, End User agrees to defend, indemnify, and hold harmless ESS and its directors, officers, employees, contract workers and from and against all liability, damages, losses, claims, demands, actions, judgments, costs, attorneys' fees, disbursements, and expenses incurred in connection with, arising out of, or resulting from End User or its employees, agents or representatives' negligence, willful misconduct, violation of applicable law, or use of the ESS Products.

6. Choice of Law. This Limited Product Warranty shall be governed by and construed in accordance with the laws of the State of Colorado, without regard to choice of law or conflict of law principles.

6.6 Batteries

The GPR Concrete Scanner uses removable lithium-ion batteries. Please be aware that, as with all lithium-ion batteries, their shipment may be classified as hazardous material. Depending on the shipment method your carrier may require a label similar to the one in Figure 10. You are responsible for complying with all requirements and restrictions of your chosen shipping carrier.

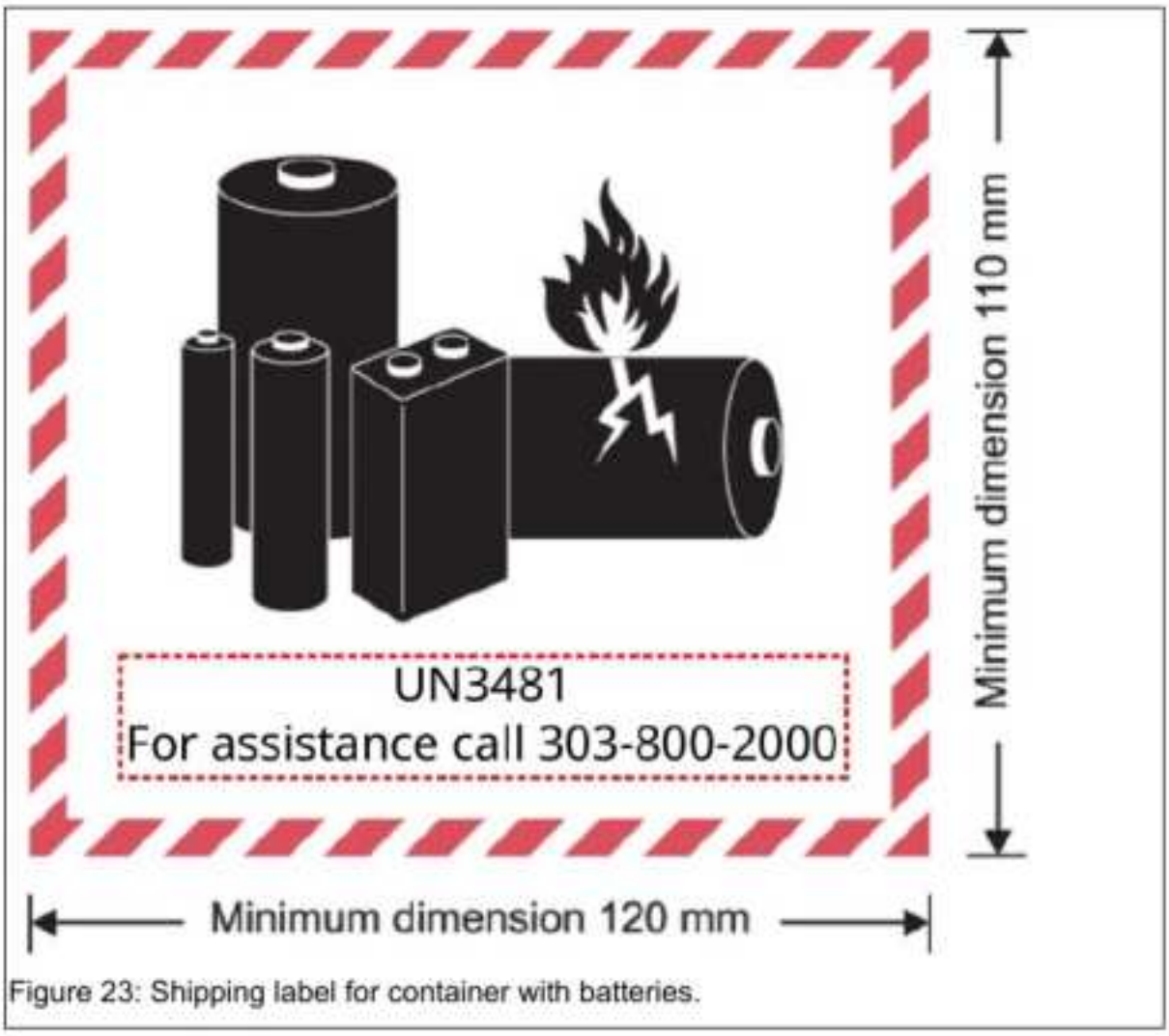

Figure 23: Shipping label for container with batteries.

Figure 10: Shipping label for container with batteries.

6.7 Technical Support

Technical support is provided by ESS between the hours of 9:00 AM and 5:00 PM MST at 303-800-2000.

6.8 Specifications

- 2 GHz bi-static radar antenna
- Magnetic field sensor for detecting power lines or tracer signals
- Integrated optical encoder
- Removable truck for floor scans
- Dimensions: 5.625 x 7.5 x 5.25 inches (without truck)
- Weight: 3.5 lb (includes battery, but without truck)
- Removable 10.8 V 6.8 Ah Lithium-Ion Batteries (qty 2)
- No cables in operation
- Durable construction with IP65 ingress protection
- Short handle for surveys within arm's reach
- Long handle for floor surveys rotates and locks into different positions
- 3D imaging software (subscription required)

6.9 Data File Format

Data recorded by the GPR system are stored using the HDF5 file format. HDF5 allows storage of large datasets in complex data structures. In addition to the data stored in an HDF5 file, the files provide all of the data type and format information needed for reading the data. A helpful utility for quickly browsing HDF5 file is the HDFView utility which is freely available from the HDF5 Group (https://www.hdfgroup.org/downloads/index.html). The HDF5 Group provides free software interfaces for HDF5 in most popular computer languages including Fortran, C, Java, Python, and Matlab. Figure 11 is a screenshot from HDFView showing the contents of an H5 file recorded by the logging system. On the left is a tree structure that lists the datasets in the file. The JobInformation dataset contains information about the jobsite. There is a folder for each data server (e.g., gpr4, odometer, etc.) on each node (e.g., the logger or the probe), and each folder contains configuration information and data. As shown below, the detailed format of each dataset is included in the file. This self-describing feature of HDF5 files along with the open software interfaces allows the data to be easily read by user-developed software.

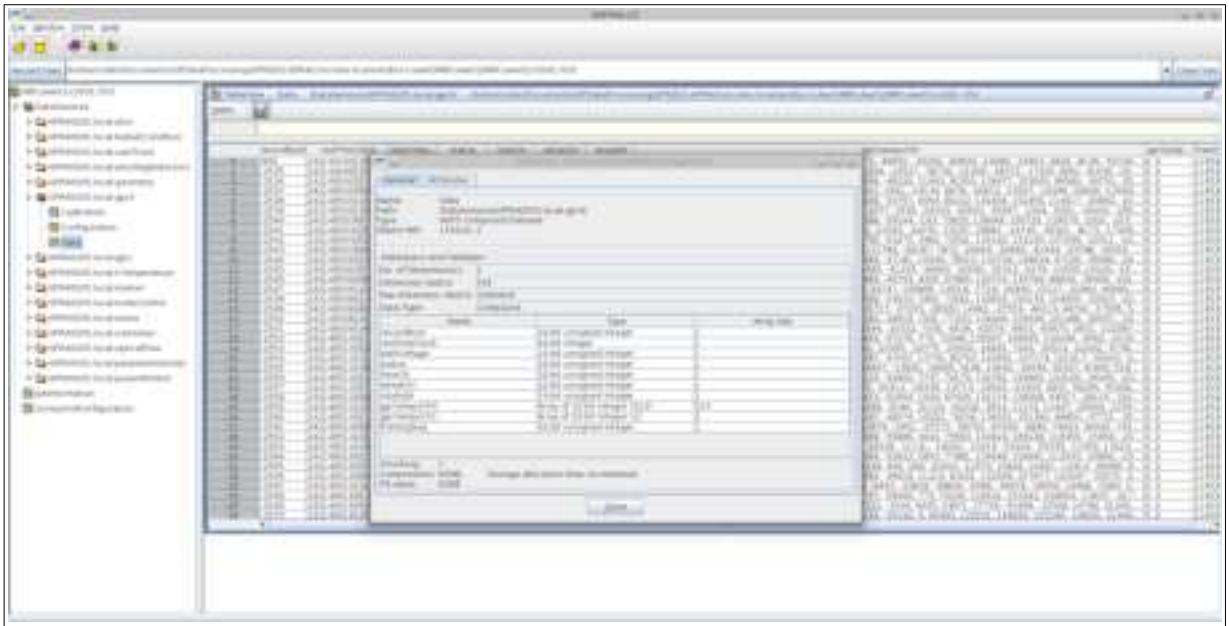

Figure 11: Screenshot from HDFView showing the contents of an H5 file recorded by the logging system.