

GPR4 Pavement 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-PS1 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.

(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, 445 12th Street, SW, 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: 2AP78-PS1 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 1 m 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 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-PS1 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) 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

This document provides the operating and configuration instructions for the Pavement Scanner. The Scanner measures pavement density, compaction, and temperature; and can generate maps and reports for the scan area. The Scanner utilizes cutting-edge radar technology to measure density without using nuclear sources. The system includes a scanner unit, a cart with an integrated wireless odometer, and a tablet computer. The Pavement Scanner has been designed so that no cables are used in order to increase ease of use and reliability. The shipping case contains an integrated battery charging system to recharge all system components simultaneously. The entire system is stored in a rugged shipping case designed for shipping and transport in rugged situations.



Figure 1: Pavement Scanner.

The system consists of the following components.

1. A hard shell shipping container with custom foam inserts for the system components.

2. A multi-port battery charging system that simultaneously charges the sensor unit, its spare battery, the wireless odometer, and the tablet computer.
3. Two batteries for the sensor unit.
4. A three wheeled cart with an integrated wireless odometer.
5. The sensor unit with GPR, IR, and GPS sensors.
6. Tablet computer (may be provided separately).

4 Operation

This section provides operating instructions for conducting surveys, generating reports, and recharging the batteries. Before starting survey, the needs to determine the area to be surveyed and how that area will be covered. The typical survey covers one or more traffic lanes over a walkable distance of typically 1000 feet (300 meters) or less. This distance will be scanned in one or more parallel lines. The pavement surface must be clean and dry. Also, users will need to determine where cores will be taken for calibration. Typically these cores are taken at the beginning of a survey or job. A specific calibration is needed for each mix or batch that comes from the plant.

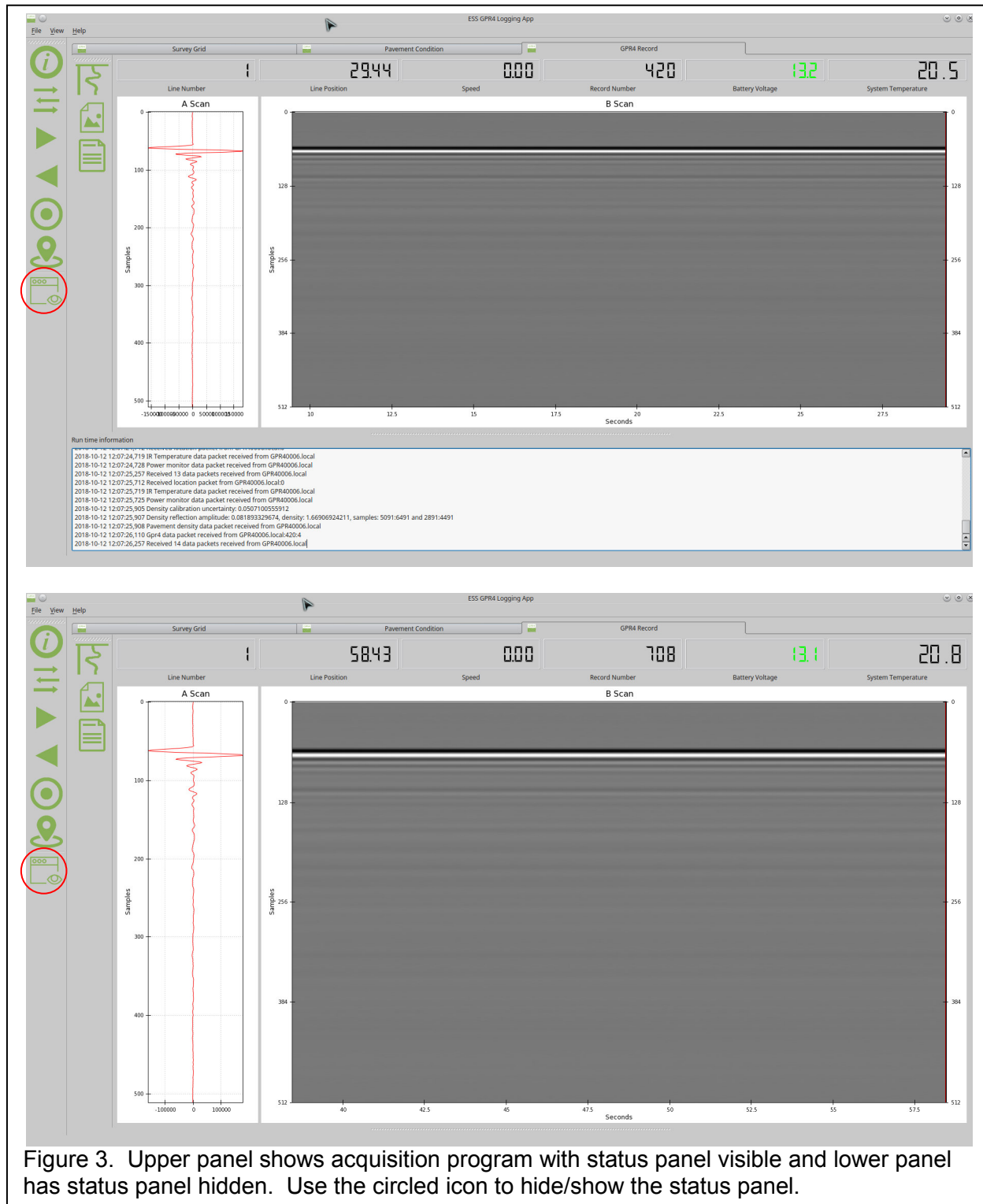


Figure 2. Pavement Scanner as stored in its shipping container.

4.1 Hardware Assembly



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

1. Open the shipping container and disconnect the charging cables from the tablet, the odometer, and the batteries.
2. Remove the wheels and legs and attached the wheels to the legs. Make sure that the wheel with the odometer target is attached to the leg with the odometer electronics, and that the target is facing the leg.
3. Place the frame assembly with the sensor unit on the ground so that the frame is on the ground and the sensor unit is on top. Attach the legs with the steerable wheels in front and the fixed wheels in the rear. When standing behind the upside-down unit, the odometer leg should be on the left with the switch facing down. Insert all push pins to hold the legs in place.
4. Turn the cart over so that the wheels are on the ground. Attached the handle and then attached the tablet to the handle.
5. Operate the unit as described in the Operation section. When finished, disassemble the frame in the reverse order and return the components to the shipping case. Make sure to remove the batteries, and connect the charging cables to the batteries, odometer, and tablet.



4.2 Conduct a Survey

To conduct a survey, proceed as follows.

1. Turn on the power to the sensor unit and the odometer. Both power switches should glow with a green light.
2. Boot up the tablet computer and log in. Enable mouse pointer using the mouse icon on the task bar if desired.
3. Connect to the sensor unit via WiFi. On the task bar, press the WiFi network icon , then select the network connection for the Pavement 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.
4. Start the data acquisition program by touching and holding the EssGpr4LoggingApp icon on the desktop. The program will startup, connect to the scanner, and start updating with data. Figure 3 shows the acquisition program screen. There is a status panel that shows status messages, but in most cases the user can hide this panel so that the plotting area is larger. The green light on the scanner's power button will flash when it is connected to the acquisition program on the tablet computer. Users can pan and zoom the plots in the acquisition program. To pan, simply click on the plot and drag. To zoom, click on the plot, press z, then click and drag to draw the zoom box. For an alternate zoom method, click on the plot, then press shift-up-arrow, shift-down-arrow, shift-left-arrow, or shift-right-arrow to zoom in the vertical or horizontal direction. To reset the plot, click on it and then press esc.
5. The acquisition program has several views that can be selected by clicking on the appropriate tab on the top of the screen: Survey Grid, Pavement Condition, and GPR4 Record. Each tab has its own toolbar with functions dedicated to that view.
6. The GPR4 Record tab has standard A-scan and B-scan plots that are customary for most GPR systems. Although this tab is not normally used when making pavement density surveys, it is useful for insuring proper system operation. The plot parameters can be changed by pressing the Plot parameters button  (see Figure X). For most users, the default settings will be sufficient. For those interested, the dialog functions are described below.
 - a. Use automatic range gain When this is selected the program automatically increases gain with increasing range to compensate for signal attenuation with range. The gain profile is automatically readjusted at the start of each line.
 - b. Automatic zero time Use this setting to move the first arrival to the beginning of the plot.
 - c. Antenna combination For the Pavement Scanner, this should always be set to TxA RxA.
 - d. Depth/Time units Select the units for the vertical scale on the B-scan. The most basic units are sample number (Samples). Sample number multiplied by the digitizer sample period gives sample time (Nanoseconds). Sample time multiplied by the medium velocity gives distance (Centimeters, Inches, Meters, Feet).

- e. Depth/Time range Users can opt to display the full range, half range, quarter range, or eighth range. Users may wish to display only a shallow portion of the usable range when interested in the more shallow portions of the surveyed range (depth).
- f. Velocity of medium The velocity of EM waves is dependent on the material type. In order to properly convert from time of flight to depth, the velocity of the medium must be selected (see Depth/Time units above). Select the medium type and the corresponding dielectric constant. The EM velocity is $v = c / \sqrt{\epsilon}$ where v is the EM wave velocity, c is the speed of light in a vacuum, and ϵ is the dielectric constant of the medium.

Air	$\epsilon = 1$
Dry concrete/indoor/mature - Dry soil	$\epsilon = 4$
Damp concrete/outdoor - Damp soil	$\epsilon = 6.5$
Moist concrete/outdoor/young - Moist soil	$\epsilon = 9$
Wet concrete/outdoor/young - Wet soil	$\epsilon = 16$
Saturated concrete/outdoor - Saturated soil	$\epsilon = 25$
- g. Distance units Select the units for the horizontal scale on the B-scan (Centimeters, Inches, Meters, Feet, Seconds).
- h. Distance range Select the horizontal range of the B-scan in distance units (10, 20, 50, 100, 200).

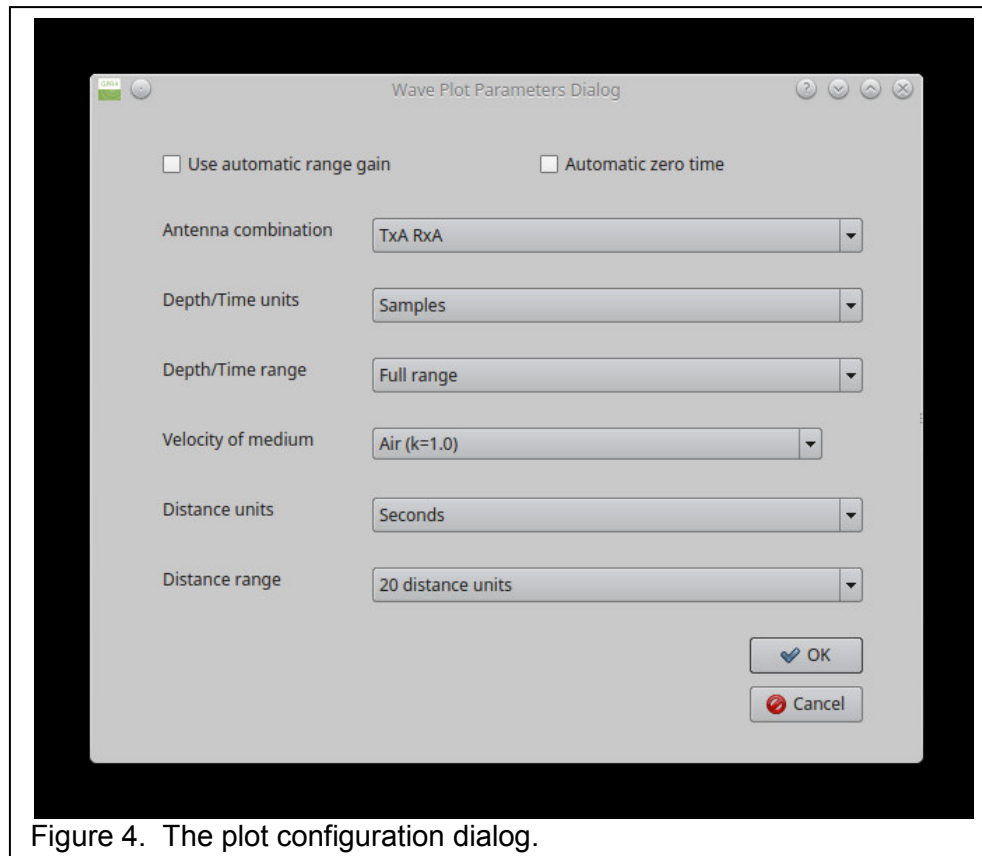






Figure 4. The plot configuration dialog.

The GPR4 Record 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.

7. The Survey Grid tab shows how the linear traverses making up the survey will be arranged. These traverses are planned using the  button and the dialog shown in Figure 5. To type into dialog field, click on the field to place the cursor, then press the  icon on the taskbar to bring up the keyboard.
 - a. Grid type Select either Single line, Parallel lines, or 2D grid (cross hatch). When conducting pavement surveys, select either Single line or Parallel lines depending in the width of the area to be scanned.
 - b. Line directions Select either Same direction or Alternating.
 - c. Lines in X-axis direction These parameters specify the beginning and ending coordinates of the lines in the X-direction, and also the distance between them.
 - d. Lines in Y-axis direction These parameters specify the beginning and ending coordinates of the lines in the Y-direction, and also the distance between them. Because lines in the Y-direction are not used for pavement scanning, these fields can be ignored.
 - e. Saving the configuration The New, Open, Save, and Delete buttons can be used to save/recall the dialog settings to/from a named configuration. This is useful when conducting a series of jobs with a similar layout.

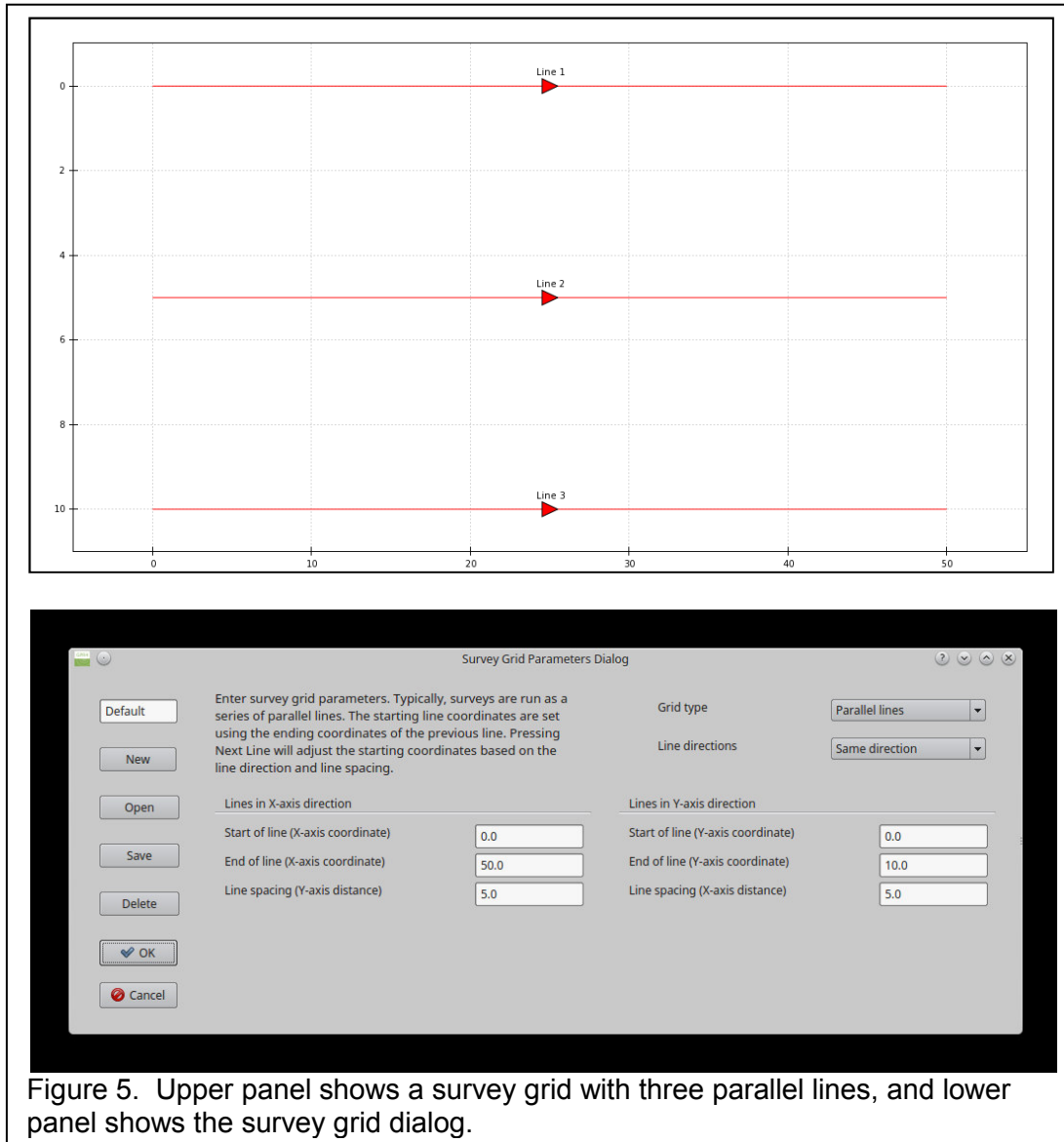




Figure 5. Upper panel shows a survey grid with three parallel lines, and lower panel shows the survey grid dialog.

8. Before beginning a survey, it is important to capture information about the jobsite. Press the Jobsite information button to bring up the dialog shown in Figure 6. The information entered into this dialog will be listed in any reports that will be generated by the software. To type into dialog field, click on the field to place the cursor, then press the  icon on the taskbar to bring up the keyboard.
 - a. Enter the Project Name, Site Location, Site Description, Operator, Survey Mode, Notes, Service Provider, and Equipment Model. The Date Recorded and Time Recorded fields will be updated automatically.
 - b. Map Frame Parameters Select the distance Units (feet or meters). The Latitude, Longitude, and Elevation parameters will be updated automatically once the survey begins using the GPS sensor in the sensor unit. The Magnetic Declination and Map System fields are not used with the Pavement Scanner.









- c. **Local Frame Parameters** Select the distance Units (feet or meters). Enter the bearing of the first survey line in the Line 1 Azimuth field. The software will use this value to correctly orient images on maps that are exported as KMZ or HTML files.

Figure 6. Jobsite information dialog.

9. Enter the calibration dialog by pressing the **Calibrate**  button. If there is an existing calibration will be used to determine density/compaction, select that calibration now by pressing the **Open** button and selecting the appropriate named calibration. Alternatively, if cores from the first part of the survey will be used to make a new calibration, press the **New** button and enter a name for the new calibration. Select the Density units: (i.e., Percent voids, Density (g/cc), Density (pcf), or Percent compaction). Finally, enter the Minimum target density and Maximum target density. These values will be used when generating reports to indicate the percentage of locations that fall within acceptable limits.

	Core number	Density	Reflection amplitude
1	1	1.0	0.05
2	2	2.0	0.1
3	3	2.5	0.155
4	4	2.7	0.166

Figure 7. Calibration dialog for density or compaction.

10. Move the scanner to the start position of the first line. For maximum accuracy in the pavement density/compaction measurement please allow the sensor unit to stabilize for 20 minutes after power up. The internal temperature stability should be less than 0.12 degrees per minute (see Internal Temperature Stability on the Pavement Condition tab).
Press the Next line or Previous line buttons  until the proper line number is displayed at the top of the screen. Each time that one of these buttons is pressed, the system runs through a line initialization sequence which takes a few seconds. When the user hears an audible beep from the tablet, the initialization sequence has completed. Therefore, users should wait until the audible beep is heard before another line request.
11. Select File, New, and then choose a location and name for the database file. When ready to begin the survey, press the Record data button . The button should appear activated to indicate that data are being recorded. Move the cart along the survey line to conduct the survey.
12. If a point is reached along a survey line where a core will be taken for calibration, stop the cart at that location and enter the calibration dialog by pressing the Calibrate  button. Press the Add Core button and then press the Use Current Amplitude button. If the actual density or compaction value is obtained at this time, it can be entered in the appropriate row. Otherwise, it can be entered later. If all of the cores for the calibration have been collected, then press the Save button and select the appropriate name for this calibration.
13. When the cart has traversed the entire survey line, press the Record data button  to turn off recording. The button should appear inactivated. Place the cart at the beginning of the next line. Make sure that the cart is precisely at the beginning of the line, otherwise there will be registration errors that appear on the map output. Press the Next line or Previous line buttons  until the proper line number is displayed at the top of the screen. Finally, press the Record data button . The button should appear activated to indicate that data are being recorded. Move the cart along the survey line to conduct the survey.
14. Repeat steps 12 and 13 as necessary. When the cart has traversed the final survey line, press the Record data button  to turn off recording. The button should appear inactivated. While recording data, a marked fiducial can be placed in the datafile by pressing the  icon.
15. If no further surveys are to be conducted, power down the sensor and odometer. Disassemble the survey cart and return all components to the shipping case.

4.3 Replaying Data




The ESS Pavement Scanner allows replaying data so that alternate calibrations applied and new reports can be generated. To replay data, follow the instructions below.

1. Insure that the scanner unit and odometer are switched off.
2. Start the data acquisition program by touching and holding the EssGpr4LoggingApp icon on the desktop. Select the Pavement Condition tab.

3. If a different mix calibration will be used, press the Calibrate button and open the appropriate max calibration. Skip this step to use the mix calibration that was originally used when recording data.
4. Press the button and input the desired grid layout that will be used when replotting the data.
5. Select File, Open, and then the file to replay.
6. When prompted, tell the program to use either the original mix calibration that was recorded with the data or the currently selected max calibration.
7. The data will replay over the course of a few minutes. When the replay is finished, users can generate reports and maps as desired.

4.4 Generating Maps and Reports

After a survey has been conducted, reports and maps can be generated.

- To save an image of either the pavement density map or the pavement temperature map, press the  icon. Select the appropriate image (density or temperature) and then the desired image file type (PNG, BMP, or JPG).
- Two types of reports can be generated. The first is a PDF file that contains the job information metadata, the calibration information, the measured pavement density statistics, and finally images of the pavement density map and pavement temperature map. The second is a CSV file that contains the job information metadata, the calibration information, and the measured pavement density measurements. The CSV file can be imported by other software packages (i.e. a spreadsheet) for further analysis and plots. Press the  button and select the desired report type and file name.
- Two different types of map files can be generated by pressing the map  icon: a Google Maps HTML and a Google Maps KMZ. The KMZ file can be opened by Google Earth and the HTML file can be opened by any web browser. The HTML file can be sent (emailed) to any smart phone for viewing in the field. Select the appropriate image (density or temperature) and then the desired map file type (HTML or KMZ). An example is shown in Figure 8.

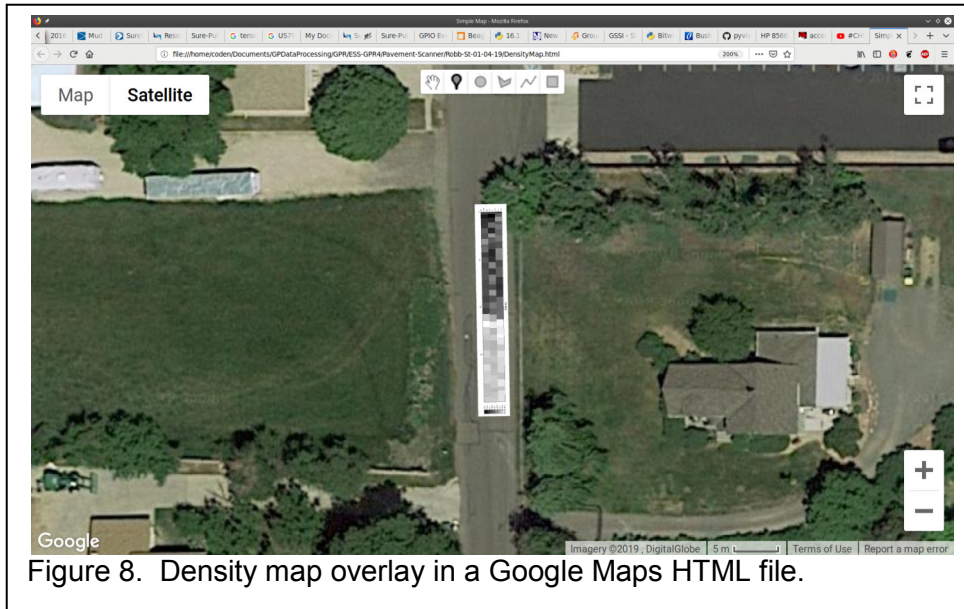


Figure 8. Density map overlay in a Google Maps HTML file.

4.5 Charging the Batteries

There are four rechargeable batteries in the system that provide sufficient power for operation over a full day. The battery in the scanner unit provides power for 4-5 hours. A second battery is provided so that surveying can continue after the first is depleted. The odometer also contains a rechargeable battery that will typically last for several days. Finally, the Microsoft Surface Pro 4 tablet contains a battery that will provide 5-8 hours of continuous operation depending on screen brightness settings. The shipping container contains an integrated battery charger that can simultaneously charge all of the batteries with only a single external power connection. 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 unit and the odometer unit. Disassemble the cart and place the components in the shipping container.
2. Remove the battery from the scanner unit and place it in one of the scanner battery charging ports in the shipping case. Place the spare scanner battery in the other charging port.
3. Connect the odometer charging cable to the odometer charge connector.
4. Connect the tablet charging cable to the tablet computer.
5. Plug the main charger power cable into 120/220 VAC mains power.
6. All batteries should charge in 4-5 hours, and all of the charge indicator lights will be green when all of the charge cycles have completed.

4.6 System Care, and Cleaning

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

5 Theory

5.1 Theory of Operation

The pavement scanner uses ground penetrating radar (GPR) and infrared (IR) sensing to characterize the surface beneath the sensing unit [1]. 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 dielectric constant of the pavement, which in turn depends on the level of compaction. The amplitude of reflected EM wave is given by

$$R = \frac{A_r}{A_i} = \frac{1 - \sqrt{\epsilon_a}}{1 + \sqrt{\epsilon_a}}$$

where R is the reflection coefficient, A_r is the reflected wave amplitude, A_i is the incident wave amplitude, and ϵ_a is the dielectric constant of the asphalt. The Pavement Scanner measures both the incident and the reflected wave amplitudes, which allows the dielectric constant of the asphalt to be calculated from the equation above. The asphalt dielectric constant ϵ_a is related to the porosity (or air fraction) of the pavement according to the CRIM equation (complex refractive index method).

$$\sqrt{\epsilon_a} = \phi_{agg} \sqrt{\epsilon_{agg}} + \phi_{bind} \sqrt{\epsilon_{bind}} + \phi_{air} \sqrt{\epsilon_{air}}$$

Here, ϵ_{agg} , ϵ_{bind} , and ϵ_{air} are the dielectric constants of the aggregate, binder, and air respectively, and ϕ_{agg} , ϕ_{bind} , and ϕ_{air} are their volume fractions (note that ϕ_{air} is also referred to as porosity).

While these relationships provide an understanding of the processes involved, the dielectric constant and volume fractions of the binder and the aggregate are not usually known. In practice, the relationship between the reflected wave amplitude and porosity is determined empirically using a polynomial curve fit and measurements taken from cores. The procedure starts by taking measurements with the Pavement Scanner and then coring those locations to determine their actual level of compaction. These data are used to calibrate the scanner response for a given type and batch of paving material. The relationship used is

$$C = a_0 + a_1 R + a_2 R^2$$

where C is compaction, density, or porosity, and a_0 , a_1 , and a_2 are calibration coefficients determined by fitting this relationship to the calibration data. Because compaction, density, and porosity are closely related parameters, this relationship can be used for all of them (although the calibration coefficients will be different for each parameter. In practice, users will select and use one of these parameters.

The IR sensor measures the amount of IR energy being radiated from the asphalt surface. The amount of IR energy emitted by the surface

$$E = \varepsilon T^4$$

where T is temperature and ε is the emissivity of the asphalt. The emissivity of a black body is 1.0, which is essentially the case for fresh asphalt. By measuring E and solving for T , the surface temperature can be surveyed using a non-contacting sensor. Because asphalt is not a perfect black body, the measured temperature may not be precisely accurate. However this measurement is very useful for locating anomalous regions where the asphalt mix is not uniform. This approach has proven useful for locating areas of segregation and other mix defects [2].

6 Appendix

6.1 Digitizer Settings

The default settings for the digitizer are sufficient for nearly all surveys. Advanced users may choose to change these settings (see Figure A1). To view or change the digitizer settings, select (*File, Settings*).

1. **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.
2. **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.
3. **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**.
4. **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.

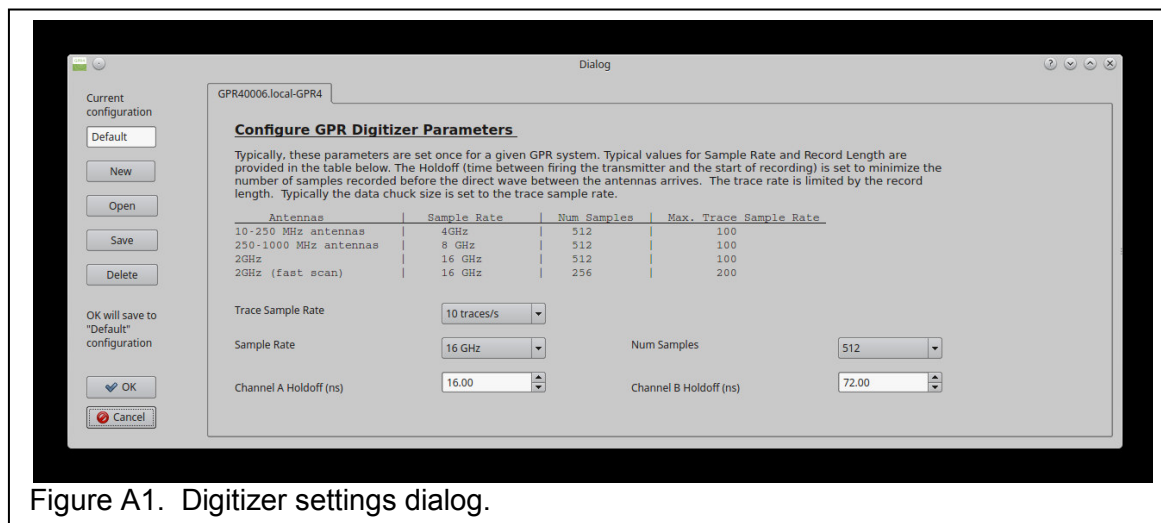


Figure A1. Digitizer settings dialog.

6.2 Software Installation

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

1. The tablet computer must use the Windows 10 operating system. The following tablet computers are approved.
 - a. Microsoft Surface Pro 4
 - b. Microsoft Surface Pro 6

- c. Microsoft Surface Go
 - d. Panasonic Toughpad FZ-G1
2. Turn on the tablet, wait for it to boot up, and then log in.
3. Press the Window icon in the lower left corner, then select Settings (the gear shaped icon). Select System, Display, and set the Resolution to 1920 x 1200. Then set the Orientation to Landscape. Finally, set Rotation lock to On. Close the Settings window.
4. Press the Window icon in the lower left corner, then select Settings (the gear shaped icon). Select System, Power & Sleep, and under Sleep set the tablet so that it Never goes to sleep under battery power or when plugged in. Close the Settings window.
5. Press and hold the task bar. Make sure the following options are checked:
 - a. Show touch keyboard button
 - b. Show touchpad button
6. Connect the thumb drive to the tablet's USB port.
7. Copy these files from the thumb drive to the desktop.
 - a. installEssPythonDistribution-x.x.x-(date).exe
 - b. installEssGpr4LoggingApp-x.x.x-(date).exe
 - c. installESSentialUnderground-x.x.x-(date).exe
8. Touch and hold the installEssPythonDistribution-x.x.x-(date).exe file on the desktop, then select Open. Follow the prompts to install this package.
9. Touch and hold the installEssGpr4LoggingApp-x.x.x-(date).exe file on the desktop, then select Open. Follow the prompts to install this package.
10. Touch and hold the installESSentialUnderground-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:

\\Earth_Science_Systems\EssGpr4LoggingApp\scripts\EssGpr4LoggingApp.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 Warranty

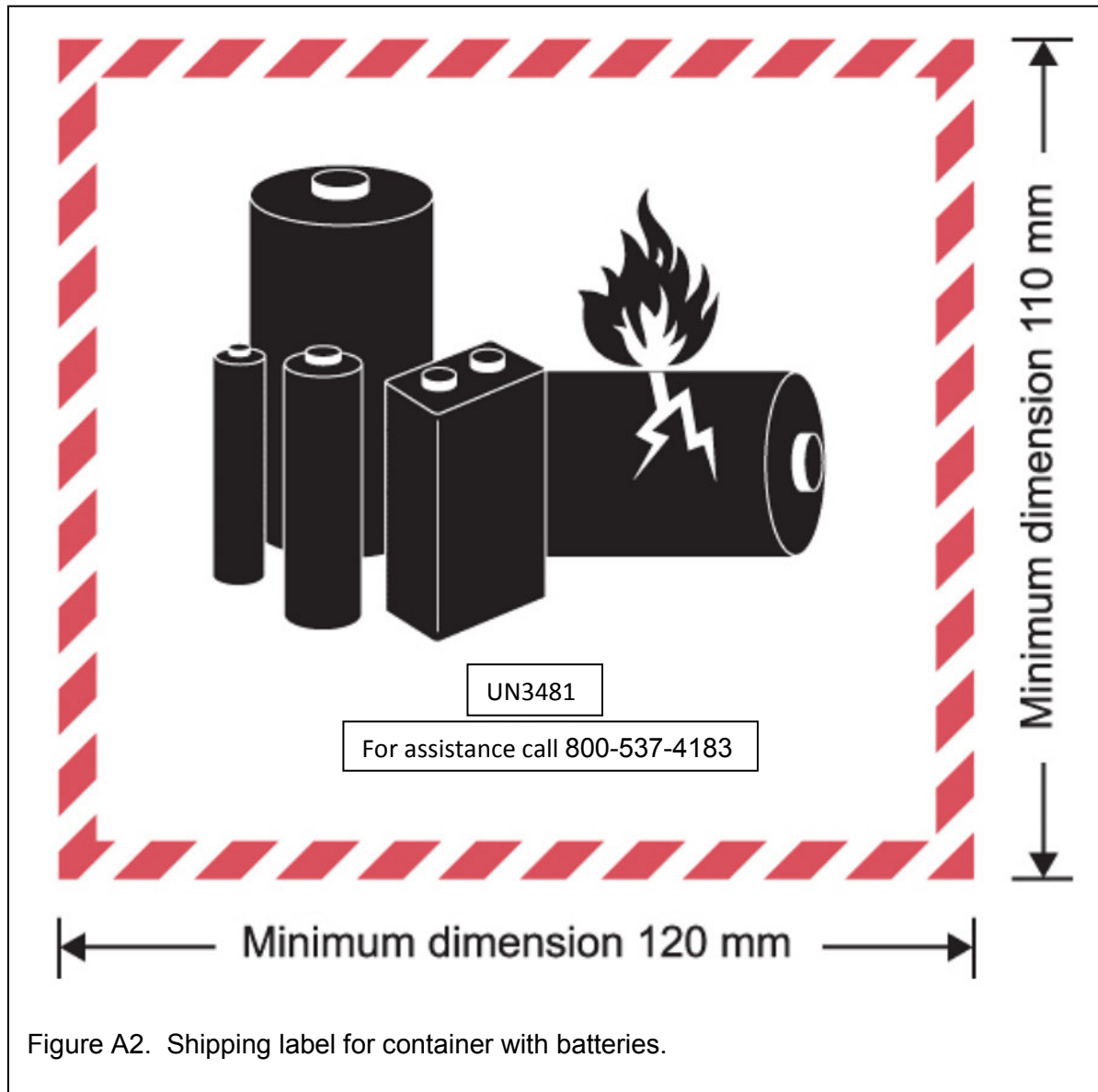
Earth Science Systems, LLC (ESS) warrants the Concrete Scanner hardware unit (PRODUCT) to be free from defect in material and workmanship under normal use for a period of one year from the date of shipment. Any computer systems purchased with the product are subject to the manufacturer's warranty and not the responsibility of ESS.

Except as specified above, the 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 PRODUCT is assumed by you. If the PRODUCT is defective or used improperly, you, and not ESS or its dealers, distributors, agents, or employees, assume the entire cost of all necessary servicing, repair or correction.

ESS 's obligation is limited to repairing or replacing parts or equipment which are returned to ESS, transportation and insurance pre-paid, without alteration or further damage, and which in ESS 's judgment, were defective or became defective during normal use. Before returning any equipment to ESS, a Return Material Authorization (RMA) number must be obtained. Please call the Customer Service Manager at Earth Science Systems, LLC who will assign an RMA number. Be sure to have the serial number of the unit available.

6.6 Batteries

The Pavement Scanner uses LiFePO4 batteries, which are one of the most efficient and long lasting batteries available. They tolerate more charge/discharge cycles than all other popular battery chemistries. For transportation purposes, they are considered lithium ion batteries and their shipment falls under UN3481. They can be shipped via air on both passenger and cargo planes, or via standard ground transportation. The following label must be present on the outside of the shipping container.



6.7 Technical Support

Technical support is provided by Humboldt Scientific, Inc. between the hours of 9:00 AM and 5:00 PM EST at 800-537-4183.

6.8 Specifications

- 2 GHz bi-static radar antenna
- Non-contacting IR temperature sensor
- Designed to be used with the Microsoft Surface Pro 4 table PC.
- Dimensions: 71.5 x 25.9 x 36.5 inches
- Shipping container dimensions: 29 x 18 x 13.8 inches
- Weight: 36.4 lbs
- WiFi connection between sensor and tablet
- Durable construction with IP65 ingress protection
- Positioning systems includes odometer, GPS, and optional inertial measurements.
- Provides continuous real-time pavement density and temperature measurements
- Generate maps of pavement density and temperature
- Calibrate the unit from core measurements
- Rechargeable LiFePO4 battery provides 5-6 hours of use. Includes second battery for all day use.

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 A3 is a screenshot from HDFView showing the contents of an H5 file recorded by the sonic 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, irTemperature, pavementDensity, 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.

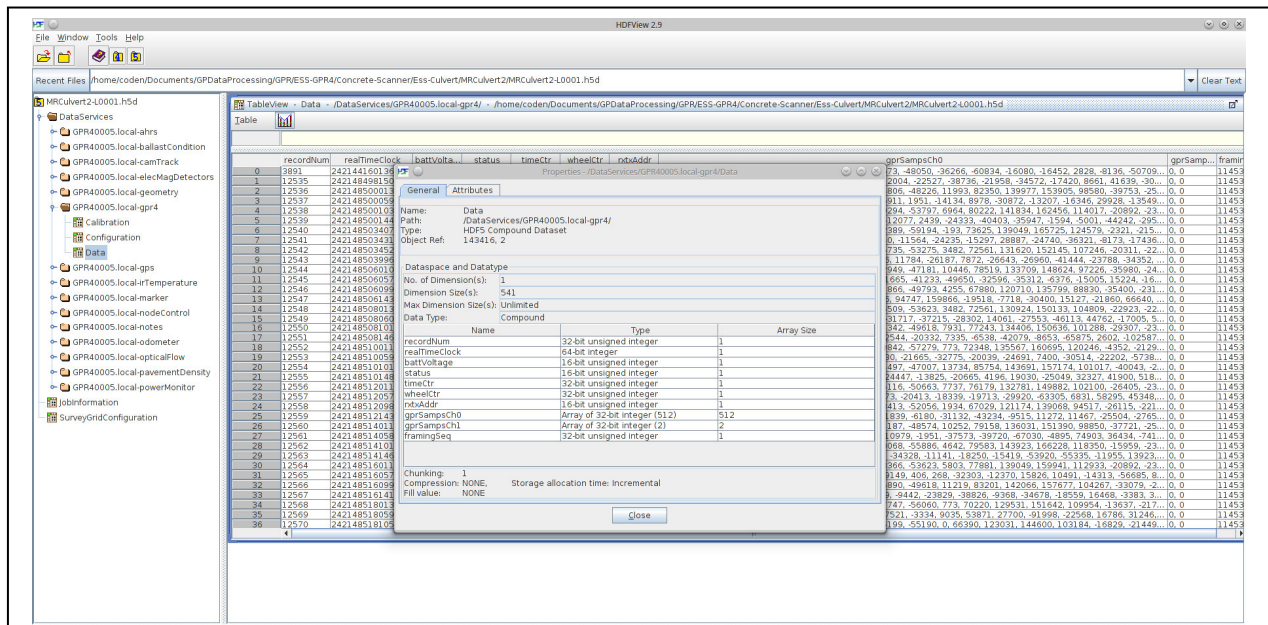


Figure A3. Screenshot from HDFView showing the contents of an H5 file recorded by the sonic logging system.

6.10 License Agreement

End User License Agreement (EULA) for EssGPR4LoggingApp

This is a legal agreement between Earth Science Systems, LLC and you, the Customer. By installing this software, you accept all the terms and conditions of this agreement. Upon your acceptance of this Agreement, Earth Science Systems, LLC grants you a non exclusive license to use one copy of the Software, provided that you agree on the following.

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USA

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ESSentialUnderground is a registered trademark of Earth Science Systems, LLC.

EssGpr4LoggingApp and ESSentialUnderground have been bundled with open source software as listed below. Notable bundled projects include: Python, Qt, VTK [BSD], and HDF5. Python modules include (Pyside, Chaco [BSD], Mayavi [BSD], Matplotlib [BSD], Numpy [BSD], and Scypi [BSD]).

6.11 References

- [1] Maser, K., and Carmichael, A., Ground Penetrating Radar Evaluation of New Pavement Density, Washington State Department of Transportation Research Office, Olympia, WA, 2015, Report No. WA-RD 839.1, 16 p.
- [2] Kim M., Phaltane P., Mohammad L., and Elseifi, M., Temperature Segregation and its Impact on the Quality and Performance of Asphalt Pavements, *Front. Struct. Civ. Eng.* 2018, 12(4): 536–547.