Radar Ballast Inspection Tool

(RABIT1)

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-RABIT1 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

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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.

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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-RABIT1 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-US1 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.

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3 FCC/IC Radiation Exposure Statement

This equipment complies with the IC/FCC RF radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with a minimum distance of 20 cm between the radiator and any part of your body.

Cet équipement est conforme aux limites d'exposition aux rayonnements énoncées pour un environnement non contrôlé. Cet équipement doit être installé et utilisé en gardant une distance de 20 cm ou plus entre le dispositif rayonnant et le corps.

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4 Introduction

4.1 Overview

This document provides the operating and configuration instructions for the Radar Ballast Inspection Tool (RABIT). The RABIT provides non-destructive measurements of ballast fouling and moisture over a 10 crib area of investigation. The scanner utilizes cutting-edge radar technology to measure ballast condition in the field without invasive digging or physical sampling. The system is comprised of the scanner unit and a tablet computer, and has been designed so that no cables are used in order to increase ease of use and reliability. The scanner also contains a GPS receiver so that reports of scan results are geo-referenced. The entire system is stored rugged shipping case is designed for shipping and transport in field situations.

Figure 1: Radar Ballast Inspection Tool (RABIT).

The system consists of the following components.

1. A hard shell shipping container with custom foam inserts for the system components.
2. Battery chargers for the RABIT and the tablet computer.
3. The sensor unit with GPR and GPS sensors.
4. Tablet computer (may be provided separately).

4.2 Theory of Operation

The RABIT uses ground penetrating radar (GPR) to characterize the surface beneath the scanner unit. The scanner sends low-energy impulses of electromagnetic (EM) energy into the subsurface and subsequently some energy is reflected back towards the sensor unit. The characteristics of reflected energy depend on the makeup of the ballast, tie geometry, and sub-surface layering. The ballast properties depend on the EM properties of the aggregate, the void filling material (i.e. fouling), and moisture. The characteristics of reflected waves are also affected by tie type (timber or concrete), tie geometry, and the layer geometry. The sub-surface layers (ballast, sub-ballast, and sub-grade) also have varying material types, varying

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thicknesses, and different types of gradation at the layer boundaries. All of these properties affect the characteristics of the reflected radar waves and a change in any property can change the reflected radar waves. A traditional approach to analyzing radar data is to use a physics-based approach that specifically accounts for each of the properties listed above; but this is difficult for such a complex problem. Neural networks are an alternative approach that is well-suited for problems involving complex pattern recognition. The RABIT system uses a neural network that has been trained using data from numerous field outings where physical ballast samples were collected and analyzed. The neural network examines each GPR waveform and estimates the ballast fouling (i.e. Selig fouling index [1]) and moisture for the depth interval 0-16 inches (0 to 40.6 cm). The details of the neural network training and analysis can be found in [2].

5 Hardware Assembly

During normal storage and transportation, the RABIT is packed in its shipping case. To unpack from the shipping case and assemble the unit, refer to Figures 2, 3, and the steps below.

Figure 2. The RABIT and its shipping container from the shipping container.

1. Open the shipping container and remove the ‘T’ handle and the three outriggers (Figure 2, right).
2. Remove the main scanner frame including the white antennas (Figure 2, left).
3. Place the frame assembly with the sensor units on the ground so that the white antenna boxes are on the ground. Attach the outriggers as shown in Figure 3. Make sure that all push pins are fully inserted.
4. Attached the push rod to the attachment point above either wheel. It doesn’t matter which attachment point (which wheel) is used.
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.

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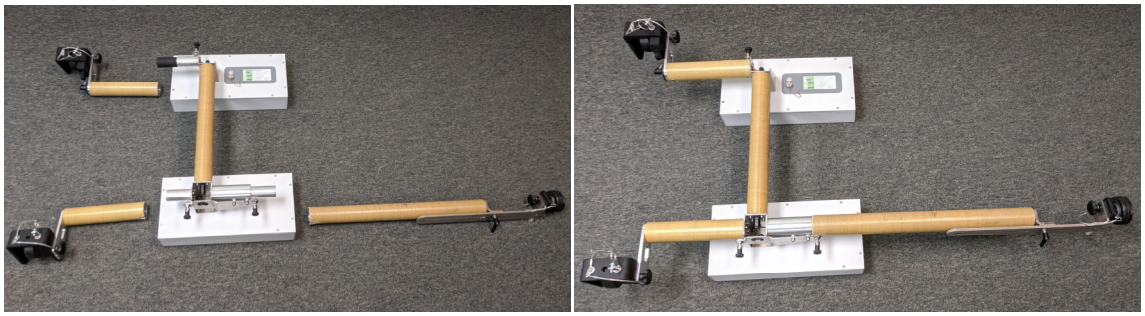

Figure 3. RABIT shown disassembled (left) and fully assembled (right).

6 Operation

This section provides operating instructions for conducting surveys, generating reports, and recharging the batteries.

6.1 Conduct a Survey

To conduct a survey, proceed as follows.

1. Turn on the power to the sensor unit. The power switch should glow with a green light.
2. Boot up the tablet computer and log in. Enable the 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, and then selecting *Run*. The program will startup, connect to the scanner, and start updating with data. Figure 4 shows the acquisition program screen. Most users choose to hide the status panel on the bottom of the screen so that the plotting area is larger, and only show the panel when diagnosing errors. The green light on the RABIT's power button will flash when it is connected via WiFi to the acquisition program on the tablet computer.
5. The acquisition program has several views that can be selected by clicking on the appropriate tab on the top of the screen: *Ballast Condition*, and *GPR4 Record*. Each tab has its own toolbar with functions dedicated to that view. Users can pan and zoom the plots in these tabs. To pan, simply click on the plot and drag. To zoom, click on the plot, press *z* (press the icon on the taskbar to bring up the keyboard), then click and drag to draw the zoom box. For an alternate zoom method, click on the plot, the press *shift-up-arrow*, *shift-down-arrow*, *shift-left-arrow*, or *shift-right-arrow* to zoom in the vertical or horizontal direction. The reset the plot, click on it and then press *esc*. Select the *Ballast Condition* tab for normal RABIT operation.

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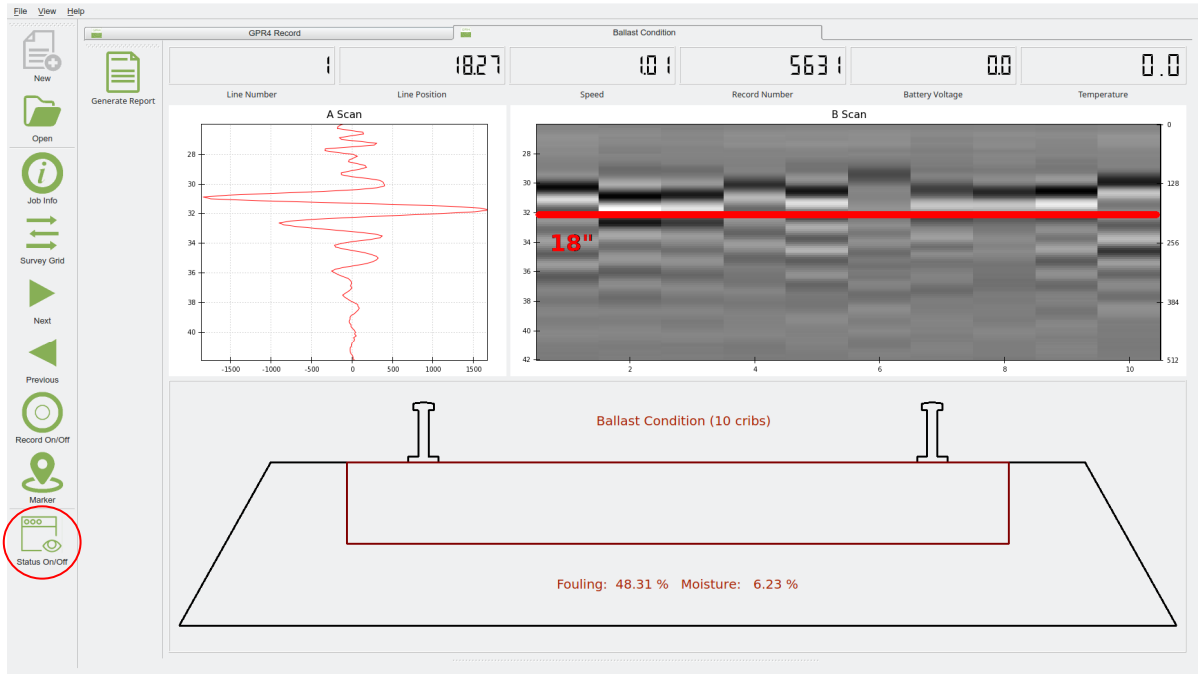

Figure 4. The EssGpr4LoggingApp. Use the circled icon to hide/show the status panel which shows detailed information that most users can ignore.

6. 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 5. 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 RABIT.
   c. *Local Frame Parameters* Select the distance *Units* (feet or meters). The *Line 1 Azimuth* field is not used with the RABIT.
7. Move the scanner to the start position in the track. Adjust the out rigger so that its wheel is centered on the rail. The scan will be made over a span of 10 cribs. Examine ballast in these cribs and insure that the ballast has filled each crib up to the top of the ties. Also make sure that any ballast material on top of the ties is removed so that the RABIT can freely roll along the track without getting caught up on any ballast material.

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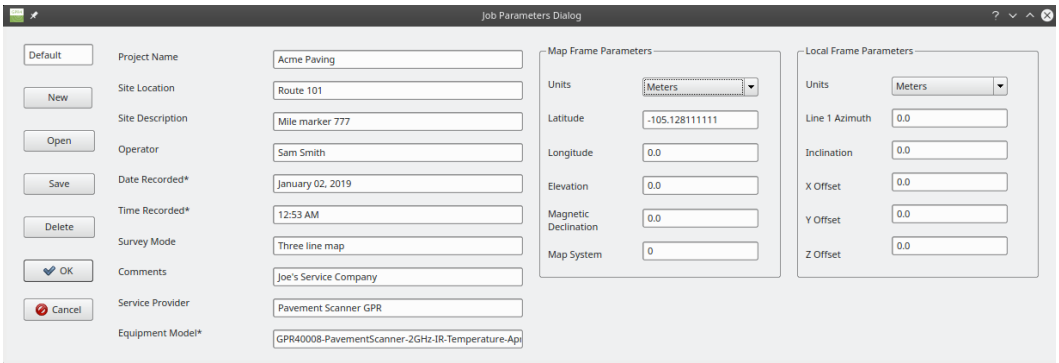

Figure 5. Jobsite information dialog.

8. 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.
9. Move the RABIT to the first tie so that the tie is midway between the two white antennas. Press the press the marker icon. Wait 10 seconds, and then advance the RABIT to the next tie and then press the marker icon. Repeat this process until 10 shots have been taken over 10 different ties. After the 10th shot has been taken, the display will update with the results of the scan (see Figure 6).

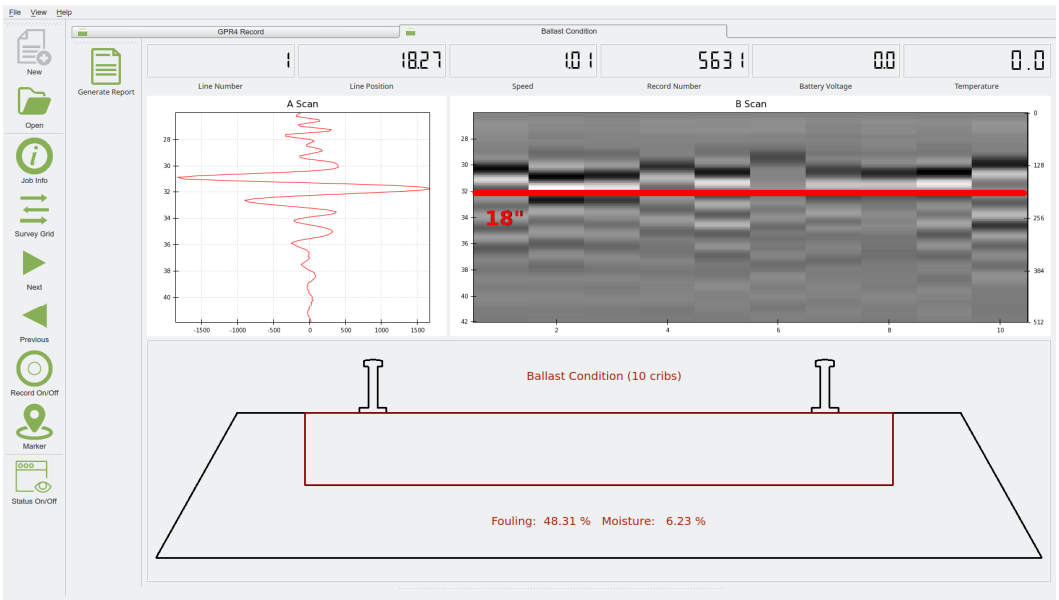

Figure 6. Ballast condition results displayed after taking 10 shots.

10. After 10 shots have been collected, press the *Record data* button to turn off recording. The button should appear inactivated. Press the button to generate a

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report that contains the job information and the scan results. The report will be stored as a PDF file.

11. If a scan is desired for the other side of the track, place the RABIT on the other rail and repeat steps 8-10.
12. After finishing a scan in a local area, the RABIT and tablet should be powered down. The battery in the RABIT should provide about 4 hours of continuous operation, and therefore the system should be powered down between survey areas so that the batteries will last for a full day's work.
13. If no further surveys are to be conducted, disassemble the outrigger arm and return all components to the shipping case.

6.2 Replaying Data

The RABIT allows replaying data so that new reports can be generated. To replay data, follow the instruction s below.

1. Insure that the RABIT is switched off.
2. Start the data acquisition program by touching and holding the *EssGpr4LoggingApp* icon on the desktop. Select the *Ballast Condition* tab.
3. Select *File*, *Open*, and then the file to replay.
4. The data will replay over the course of a few minutes. When the replay is finished, users can generate reports as desired.

6.3 Charging the Batteries

The rechargeable batteries in the system provide sufficient power for operation over a full day if the RABIT and the tablet computer are switched off between surveys. The battery in the scanner unit and the tablet provides power for about 4 hours of continuous operation. Finally, the Microsoft Surface Pro 4 (or Panasonic Tough Pad) tablet 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 RABIT and the tablet computer. Disassemble the RABIT and place the components in the shipping container.
2. Connect the RABIT charger connector to the charge port on top of the RABIT. Connect the tablet computer charger connector to the tablet.
3. Plug both the tablet charger and the RABIT charger main power cables into 120/220 VAC mains power.
4. 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.

6.4 System Care, and Cleaning

The RABIT should be kept clean and free of debris. This is especially important if the unit has picked up grease from the track. The sensor unit can be wiped clean with water and a mild detergent.

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7 Appendix

7.1 Software Installation

If the tablet computer has not yet been setup for use with the RABIT II 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. Dell Latitude 7212
    b. Microsoft Surface Pro 6
    c. 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
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.

7.2 Additional Software Settings

The data acquisition program (Gpr4LoggingApp) is a general purpose program that is used for several different applications. There are some controls and settings in this program that are not normally used for the ballast condition application. Nevertheless, they are included in this section for completeness.

7.2.1 GPR4 Record Tab Settings

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 ballast surveys, it is useful for insuring proper system operation. The plot parameters can be changed by pressing the *Plot parameters* button (see Figure A1). For most users, the default settings will be sufficient. For those interested, the plot configuration parameters are described below.

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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 selected (see *Depth/Time units* above). Select the medium type and the corresponding dielectric constant. The EM velocity is $v = c/\sqrt{\varepsilon}$ 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	ε = 1
Dry concrete/indoor/mature - Dry soil	ε = 4
Damp concrete/outdoor - Damp soil	ε = 6.5
Moist concrete/outdoor/young - Moist soil	ε = 9
Wet concrete/outdoor/young - Wet soil	ε = 16
Saturated concrete/outdoor - Saturated soil	ε = 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*).

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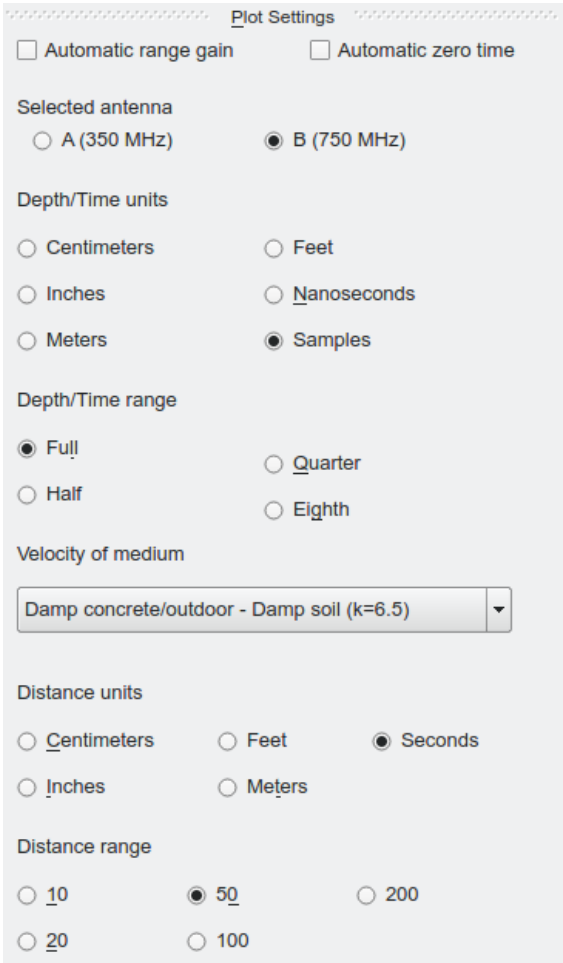

Figure A1. The plot configuration dock.

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.

7.2.2 Digitizer Settings

The default settings for the digitizer are sufficient for nearly all surveys. Advanced users may choose to change these settings (see Figure A2). 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. Use 10 traces/s for the RABIT.
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. Use 8 GHz for the RABIT.

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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*. Use 512 samples for the RABIT.
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.

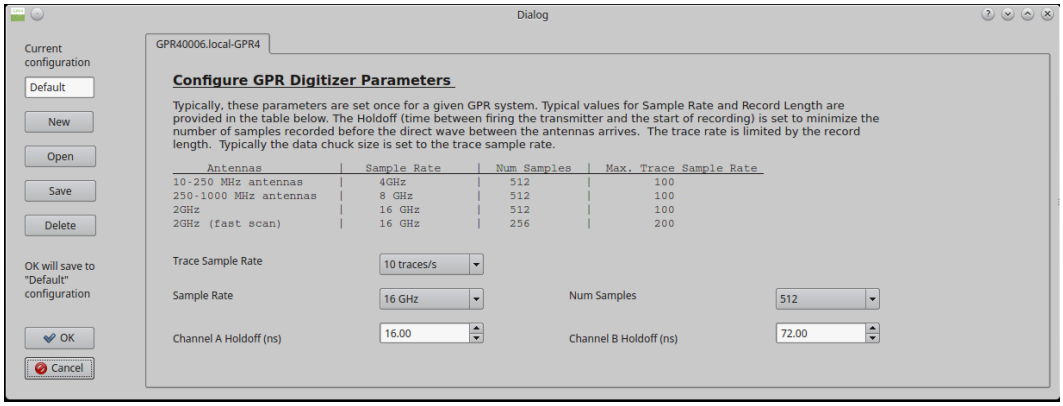

Figure A2. Digitizer settings dialog.

7.2.3 Previous and Next Line Buttons

Multiple survey lines are not used when making RABIT surveys, so the *Next line* or *Previous line* buttons are not used. After pressing one of these buttons, 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 (and therefore, users should wait until the audible beep is heard before another line request).

7.3 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.

7.4 Emissions

7.4.1 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.

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7.5 Limited Warranty

Earth Science Systems, LLC (ESS) warrants the Pavement 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 Humboldt Manufacturing Co., Inc. who will assign an RMA number. Be sure to have the serial number of the unit available.

7.6 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.

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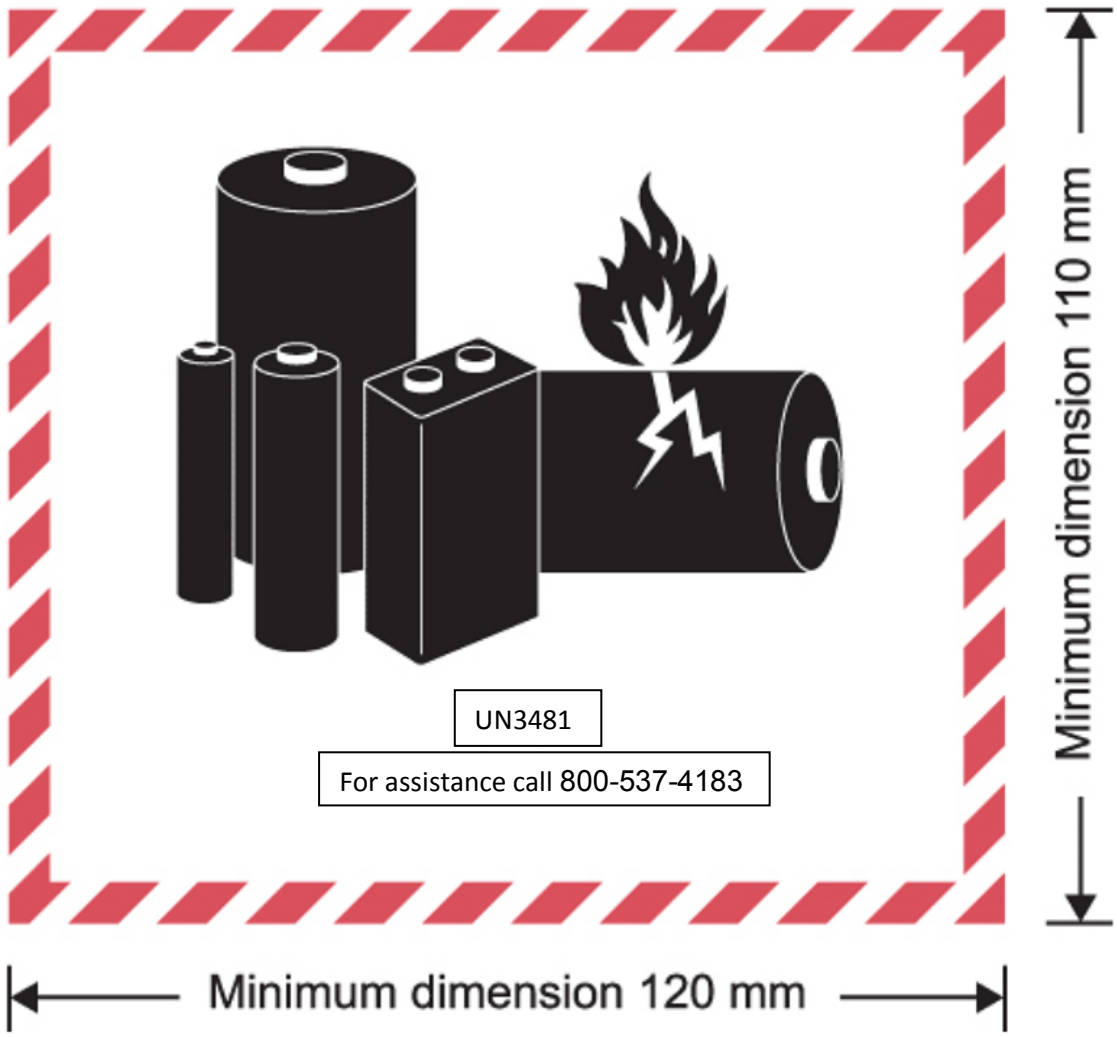

Figure A3. Shipping label for container with batteries.

7.7 Technical Support

Technical support is provided by Earth Science Systems, LLC between the hours of 9:00 AM and 5:00 PM EST at 303-800-2000.

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7.8 Specifications

- 500 MHz bi-static radar antenna
- Designed to be used with the Microsoft Surface Pro 4 tablet (or Panasonic Tough Pad).
- Dimensions: 30.5 x 11 x 49.5 inches (77.5 x 27.9 x 125.7 cm).
- Weight: 26.6 lbs. (12.1 kg).
- Shipping container dimensions: 33.4 x 22.0 x 12.9 inches (84.8 x 55.9 x 32.8 cm).
- Shipping weight: 69 lbs (31.3 kg).
- WiFi connection between sensor and tablet.
- Durable construction with IP65 ingress protection.
- Positioning systems includes odometer, GPS, and optional inertial measurements.
- Generate reports of ballast condition.
- Rechargeable LiFePO4 battery provides 5-6 hours of use. Includes second battery for all day use.

7.9 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 5 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.

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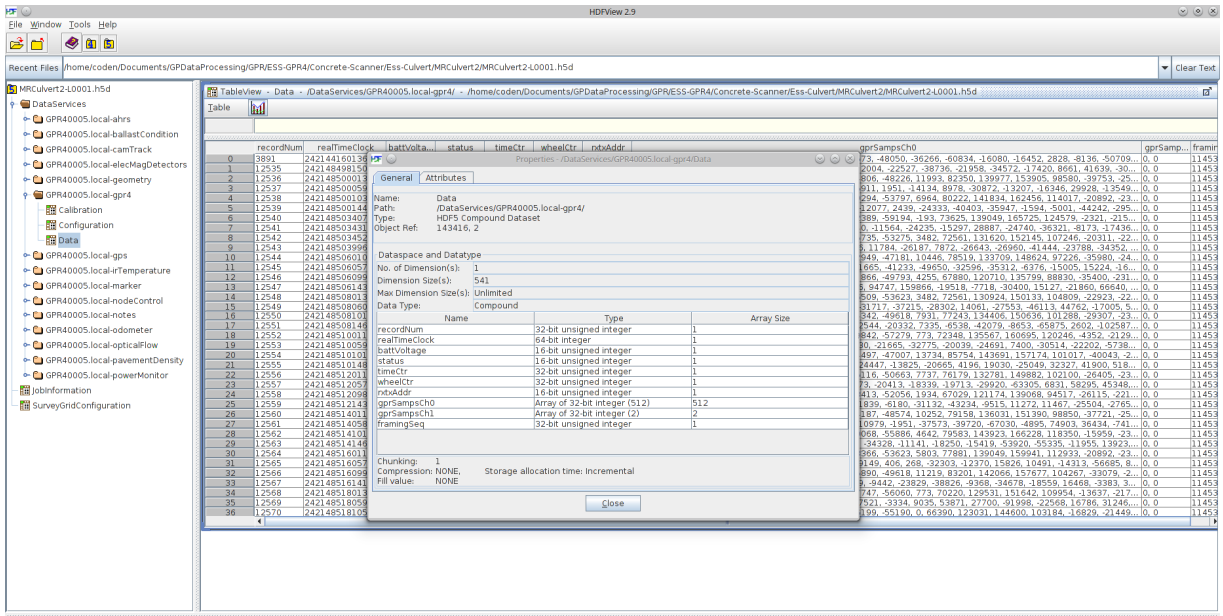

Figure 12. Screenshot from HDFView showing the contents of an H5 file recorded by the sonic logging system.

7.10 License Agreement

End User License Agreement (EULA) for EssGPR4LoggingApp

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EssGpr4LoggingApp has 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]).

7.11 References

[1] Selig, E. T., and Waters J. M., 1994, Track Geotechnology and Substructure Management, T. Telford, London.

[2] Oden, C. P., Ho, C. L., and Rubin, A. J., 2018, Final Report for FRA-TR-010: Ballast Fouling Measurement Tool – Phase III, Federal Railroad Administration, Washington, D.C.