GROUND POSITIONING RADAR™

GPR User Manual

Version 1.4

Limited Warranty, and Limitations of Liability and Restrictions

GPR UWB Compliance Notice

The FCC has granted GPR, Inc. a limited waiver of sections 15.509(b) and 15.525 so that the GroundSense® system and its accessories can now be granted UWB certification. This action was adopted and released by the Chief of the Office of Engineering and Technology (OET) on 02 November 2023 and is described in DA 23-1041 and DA-23-1109. This waiver is subject to the following conditions:

1. The GPR system shall be certified by a designated Telecommunication Certification Body and must comply with the technical specifications applicable to operation under Part 15 of 47 CFR, except as permitted below:
    a. The operational limitations in 47 CFR § 15.509(b) are waived to permit the operation of the GPR system by the general public.
    b. The requirement in 47 CFR § 15.525 requiring coordination of devices with the federal government through the Office of Engineering and Technology prior to operation is waived.
2. The GPR device shall operate only in the bands 137-322 MHz and 335.4-400 MHz. It shall not produce intentional emissions below 137 MHz, above 400 MHz or in the 322-335.4 MHz band. Emissions below 137 MHz and above 400 MHz must comply with the applicable limits, e.g., those in Section 15.209 at frequencies at or below 960 MHz and those in Section 15.509 at frequencies above 960 MHz.
3. Emissions from the GPR device in the following bands shall not exceed the following limits, measured using a CISPR quasi-peak detector as specified in Section 15.209(d):
    a. 320.6-322 MHz: linearly interpolated between the Section 15.209(a) limit at the lower end of the band and 10 dB below the Section 15.209(a) limit at the upper end of the band.
    b. 322-335.4 MHz: 10 dB below the Section 15.209(a) limit.
    c. 335.4-336.8 MHz: linearly interpolated between 10 dB below the Section 15.209(a) limit at the lower end of the band and the Section 15.209(a) limit at the upper end of the band.
4. The GPR device shall comply with all other technical and operational requirements applicable to UWB ground penetrating radar devices under Part 15, Subpart F of the Commission's rules.
5. The GPR device may operate only when mounted under a vehicle and pointed at the ground.
7. The GPR device may not operate when the vehicle ignition is turned off.
8. If more than one GPR device is installed on a vehicle, the devices must transmit independently (e.g., non-synchronously).
9. GPR shall include conditions 5, 7 and 8 above in its sale contracts with its customers.

10. Sales of the GPR device authorized under this waiver grant shall be limited to 30,000 vehicles, of which up to 1,000 vehicles shall be permitted to incorporate two GPR units, for a total of up to 31,000 GPR units. Deployments of the GPR device after 2024 may be increased subject to agreement with the Commission and the concurrence of NTIA.
11. GPR shall promptly report any incidents of interference attributable to the GPR device to the Commission and shall provide a copy of such report to NTIA.
12. Within 60 days after December 31, 2024, GPR shall file with the Commission a report containing the details of its U.S. deployments of the GPR device. A copy of such report shall be provided to NTIA. The report may include information about deployments of the GPR device outside the United States.
13. The waiver conditions granted herein are not transferable to any third party via §2.933 or any other means of technology transfer.
14. This waiver and its conditions shall apply only to the UWB devices described herein and are not to be considered to apply generally to any other UWB operations where further analysis would be necessary to assess the potential for impact to other authorized users.
15. A copy of this Order shall be provided with the application for certification of the device.

FCC Class A Compliance

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

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.

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment or residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the introduction manual, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation.

Canadian Emissions Requirements

This Class A digital apparatus complies with Canadian ICES-003 and RSS-220.

Cet appareil numérique de classe A est conforme aux normes canadiennes ICES-003 et RSS-220.

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Introduction

The following user manual shall provide the necessary information to run standard operations with the GPR sensor in the vehicle and perform basic troubleshooting in the case of any issues.

Note: Definitions for various terms can be found at the end of the document in the Glossary section

System Diagram

Figure 1 outlines the devices and communication of information within the GPR system.

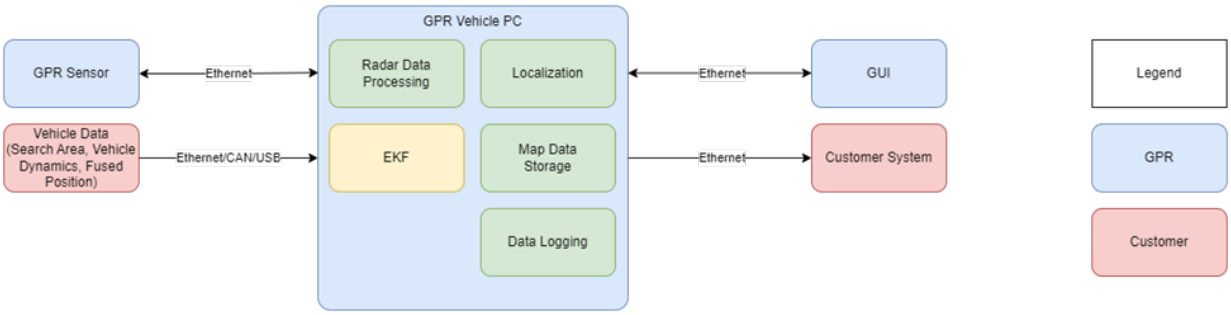

Figure 1: GPR System Diagram

Each computer is used for a different purpose as detailed below:

- *ECU:* Runs the following containerized applications:
  - LGPR: Localization application
  - GPRmap: Mapping application
  - Sensor Logger: Data logging application
- *GUI:* Laptop which runs the SCAN GUI and allows user to request operations such as calibration, mapping, map processing, localization, and offloading.

System Functions

In the vehicle, the GPR system can perform the following operations:

- Calibration
- Mapping
- Localization
- Offloading Data

Each operation listed above is requested through the SCAN GUI.

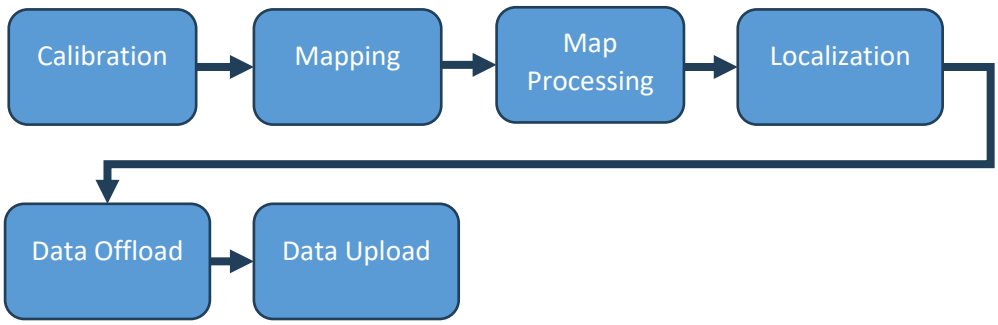

Figure 2: High-Level Standard Operations.

Calibration is the one-time process of setting a baseline for the GPR system. Calibration must be completed before performing an operation such as Mapping or Localization. If calibration data already exists on the vehicle, it is not necessary to calibrate the sensor again.

Mapping is the process of collecting GPR and vehicle position data to generate a map. To complete a mapping operation, a calibration file is needed.

Localization is the process of positioning the vehicle using previously collected and processed map data. To complete a localization operation, a calibration file and map are needed.

Offloading Data is the process of transferring data from a GPR vehicle to an external drive. To complete an offloading operation, there must be calibration files, non-processed maps, or localization run files on the vehicle. During the offloading process, it is possible to delete all the data from the vehicle or retain post-processed maps. *Note: External drives shall be provided by GPR for the duration of the program.*

Uploading Data is the process of transferring map and/or localization data to GPR cloud for analysis. This is performed automatically following an offload if internet connectivity is available.

Data Transfer Application

Data Transfer Application runs on the provided GUI Laptop that serves two purposes: uploading data and downloading processed map data. Both purposes intend to transfer data to/from the GPR vehicle. External drives shall be provided by GPR to transfer the data.

Vehicle Usage

Turning On GPR System

1. If driver is taking vehicle out of the garage, make sure to unplug the vehicle battery charger.
2. If a hotspot is being used for in-vehicle connectivity, turn on hotspot. Ensure network connection for hotspot is good.
    a. When GPR system is powered on, hotspot is charged via USB to UI PC.
    b. When GPR system is powered off, hotspot will remain on using battery power unless physically turned off by pressing power button on device. Due to risk of running out of power when GPR system is off, hotspot should be turned on only when GPR system is in use.
3. Turn on Master switch first.
4. Turn on Monitor switch.
5. Turn on Computer switch.

Turning Off GPR System

1. Turn off vehicle.
2. Turn off Computer switch.
3. Wait until computer shuts down (displayed on front monitor).
    a. Process should take about 1 minute.
4. Turn off Monitor switch.
5. Turn off Master switch.
6. If a hotspot is being used, turn off hotspot.
7. If vehicle is going to remain in garage for an extended period of time, connect vehicle to 12V battery charger.

Operating GPR Software

System Startup

Login to GUI (Refer to *Navigating SCAN: Login* instructions)

After GPR system has started up (powered on) for the first time, the GUI will take approximately a minute to automatically load the GUI screen. **Do not** launch the “scan” application manually unless restarting the GUI software.

Ensure that the hotspot is turned on and has good network connection before the system starts up.

Figure 3: Empty Terminal to Start GUI

Navigating SCAN (GPR GUI)

GUI will start up automatically when the computer turns on for the first time.

Login

When the GUI first loads, the login screen will appear.

1. User must enter the username as listed below.
    - Username: Gpr
    - Password: GprGpr
2. Select “Submit”.

Figure 4: Login Screen on SCAN interface

After username and password are entered, the GUI will load and take about 3 minutes to initialize which can be seen by the “Initializing” state in the top right corner of the screen.

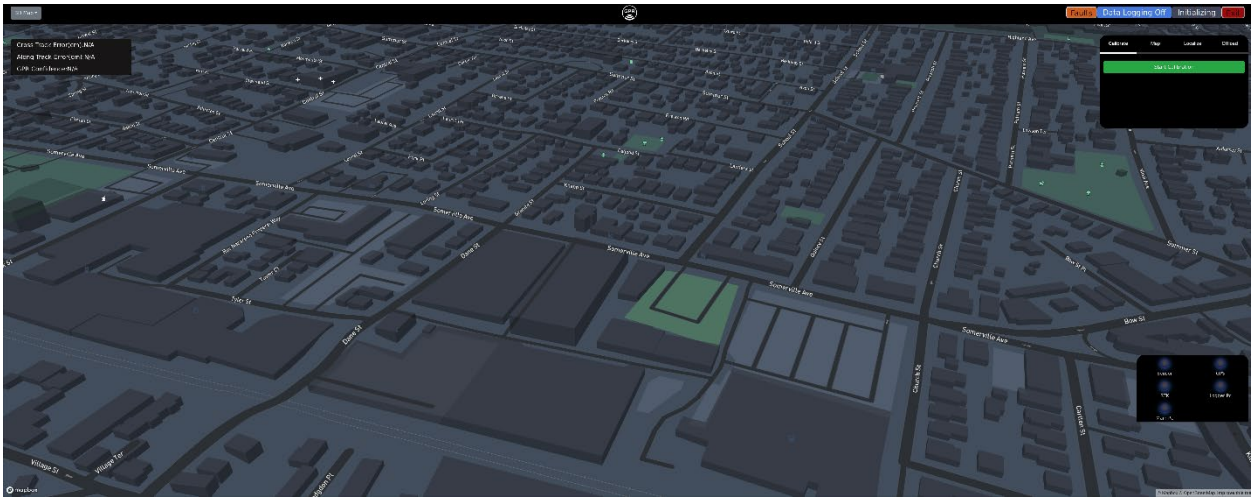

Figure 5: SCAN interface when "Initializing"

When state changes to "Ready", user can start following instructions for operations.

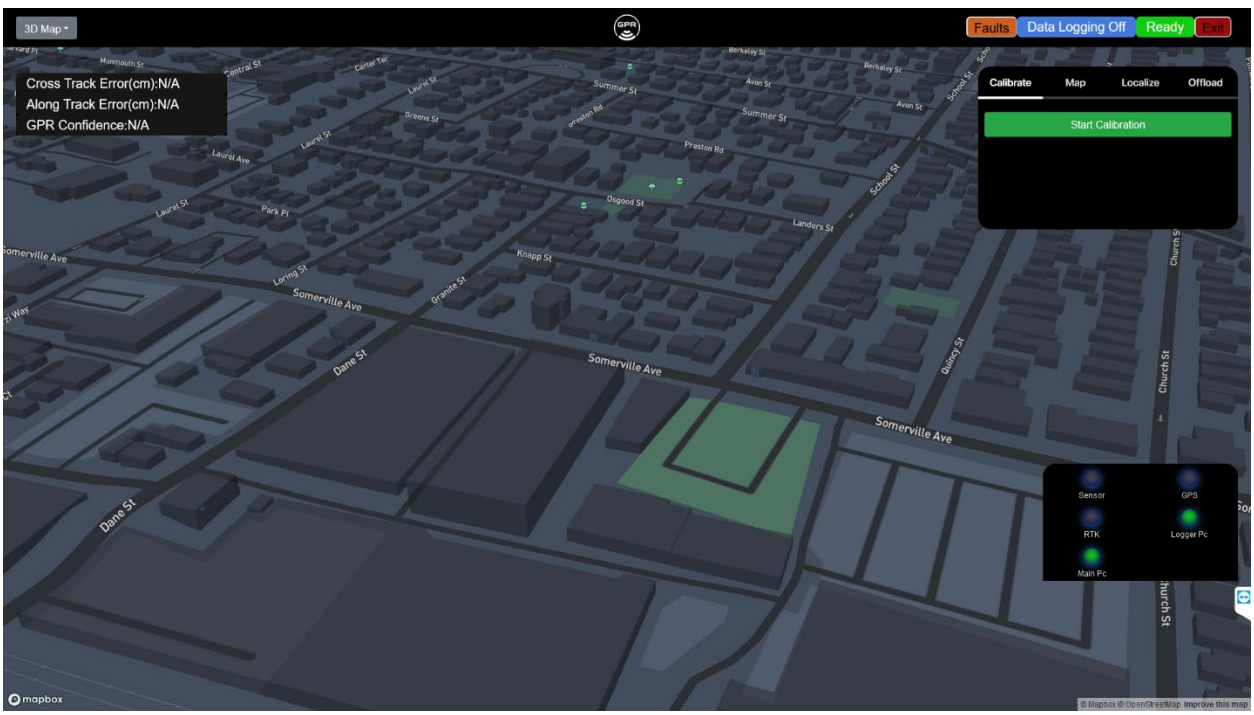

Figure 6: SCAN interface when "Ready"

Calibration

If required, calibration has to be performed using the GoCal utility as follows:

1. From the GUI Laptop, use the GoCal application shortcut to start the GoCal application
2. In the GoCal application, select "Start Calibartion"
3. Select "Verify Calibration" (password: gpr). If verification fails, see Troubleshooting Section
4. Select "Save Calibration" and enter the height of the sensor above ground in inches

Figure 7: GoCal Application

Mapping

To create a map, use the “Map” tab of the SCAN GUI:

1. Select “Mapping” tab. If mapping operation was completed right before, switch to another tab and come back to “Mapping” back.
2. Select “**Protobuf**” as GPS option.
3. Input ID number for associated test.
4. Select route name from list. If route name is unavailable, select “Custom” and type in route name.
5. Select “Start Mapping”.
6. Wait 30 seconds and drive along route you want to map.
7. GPR sensor takes 20 meters to initialize before mapping begins.
8. **Do not** drive a route longer than 3 hours
9. **Do not** drive faster than 110 kph.
10. Select “Stop Mapping” when driven route is complete.

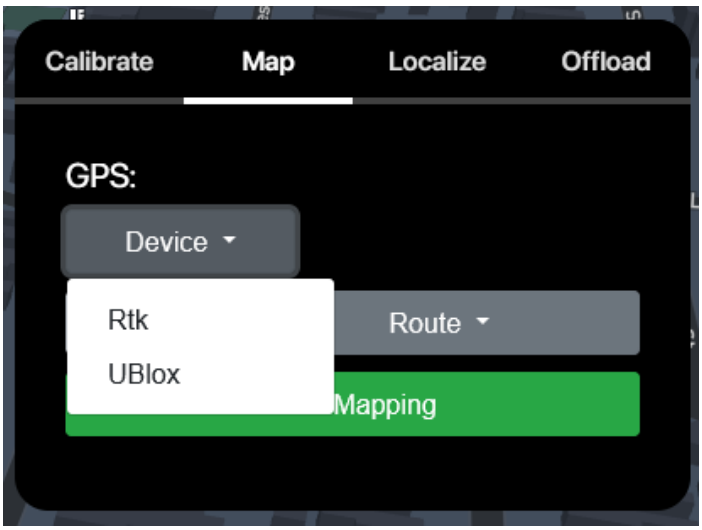

Figure 8: Select GPS device option in “Map” tab

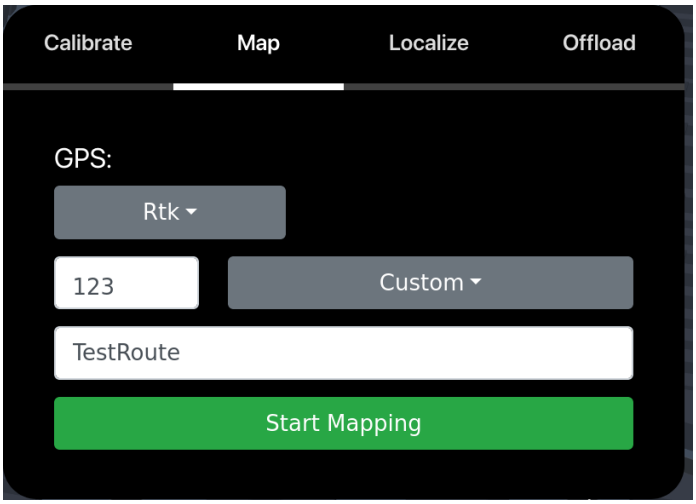

Figure 9: Selected “Rtk” device, input ID as “123”, selected “Custom” route with name “TestRoute”

Map Processing

Use the GUI Laptop to process a collected map:

1. Launch via the Map shortcut on the GUI Laptop
2. Use App Mode to identify location of ground truth
3. Select the .raw (GPR data file format) to process
4. Select the vehicle
5. If using external truth file, specify it's location

Localization

1. If map has not been collected, follow *Mapping* instructions. If map needs to be loaded, follow *Loading Maps* instructions.
2. Select "Localize" tab. If localization operation was completed right before or Localization option is greyed out, switch to another tab and come back to "Localize" tab. This prevents accidentally starting undesired localizations.
3. Select map from dropdown list first.
4. Selecting the GPS option or inputting the ID number before selecting the map will not show a map option. Change tabs and come back to Localization tab if process is followed out of order.
5. If map is not available and needs to be loaded, refer to *Loading Maps* instructions.
6. Select "Protobuf" as GPS option and input ID number for associated test.
7. Select "Start Localization".
8. Wait 30 seconds and drive along map to collect localization data.
9. GPR sensor takes 20 meters to initialize before localization begins.
10. Select "Stop Localization: when driven route is complete.

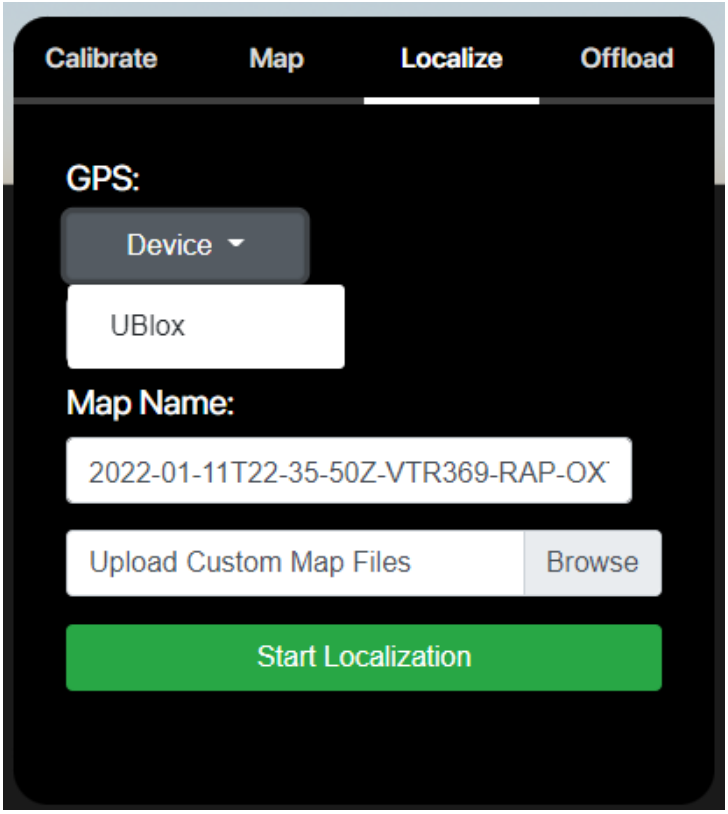

Figure 10: Select GPS device option in "Localize" tab

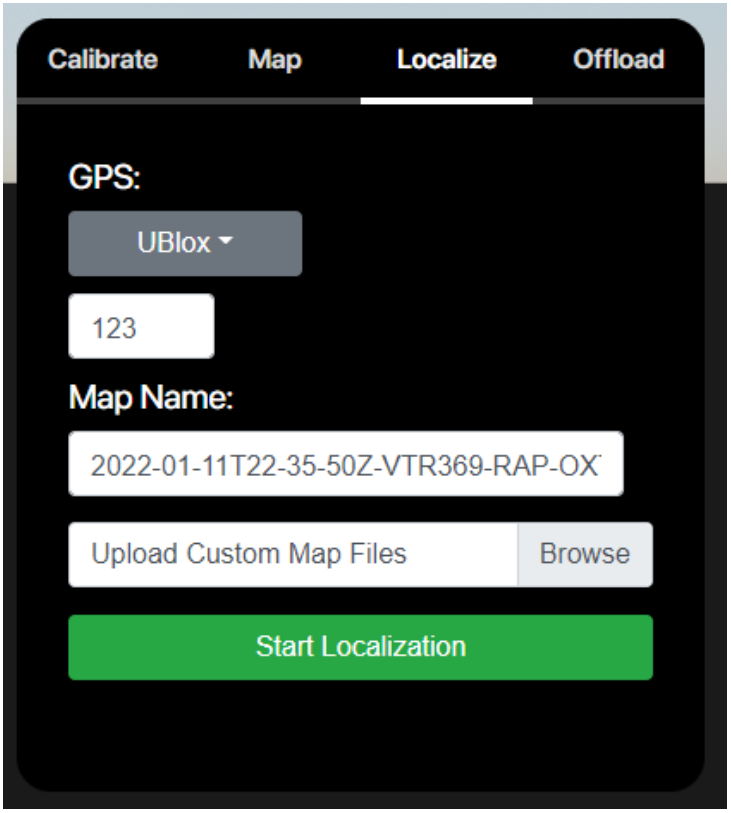

Figure 11: Selected "UBlox" device, input ID as "123", selected map as "2021-01-11"

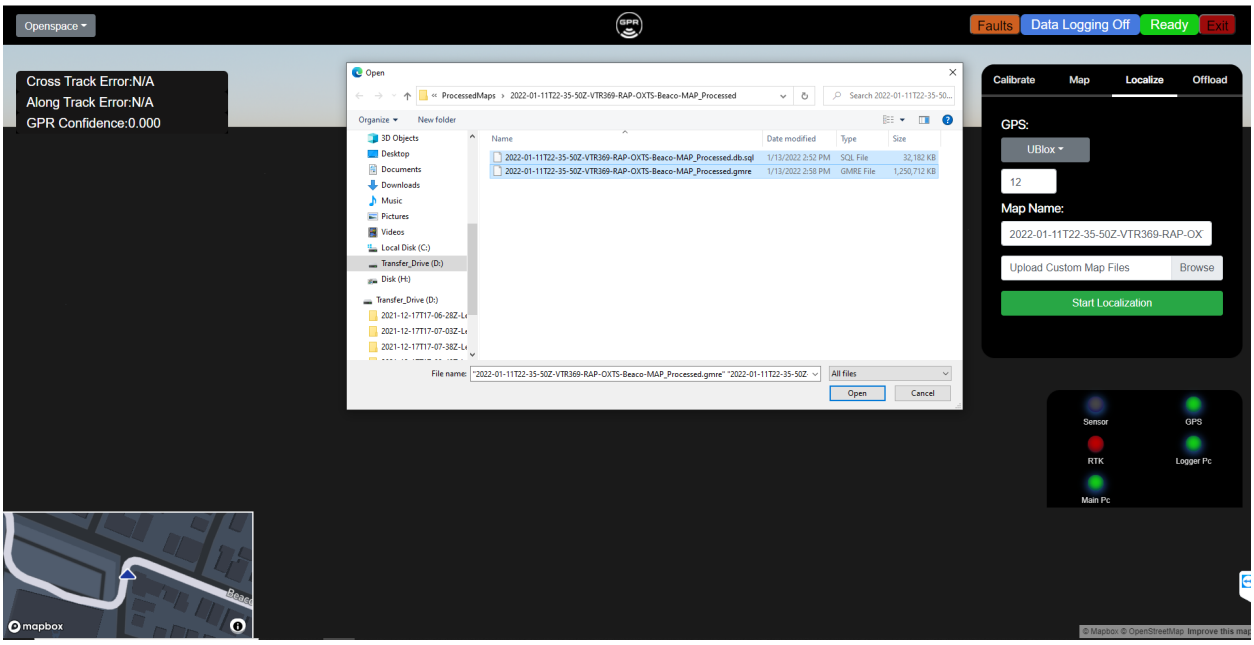

Figure 12: Map Files Selected (.gmre and .db.sql) under File Structure (ProcessedMaps/<Run Name>/<Files>)

Offloading Data

1. Connect removable drive to GUI Laptop
2. Select "Offload" tab.
3. Select "Start Offloading".
    - Default and recommended option is to Delete Unprocessed
    - Option to select: Delete Processed, Delete Unprocessed, Keep All Maps, Delete All
        - Delete Processed = Deletes localization runs and processed maps
        - Delete Unprocessed = Deletes localization runs and unprocessed maps
        - Keep All Maps = Deletes calibrations and localization runs
        - Delete All = Deletes localization runs, processed maps, and unprocessed maps
5. Once offloading is complete, remove drive from computer.
    - Offloading is complete when the status bar in the top right corner of the screen says "Ready"
    - Estimated time to offload a 1 hour map or localization run[1] is approximately 12.5 minutes.
6. Follow *Uploading Data* instructions.

[1] Assumes average speed of 110 kph when mapping or localizing and fully available computer resources during offloading process.

Figure 13: Removable Drive Cable to be Plugged into the UI PC

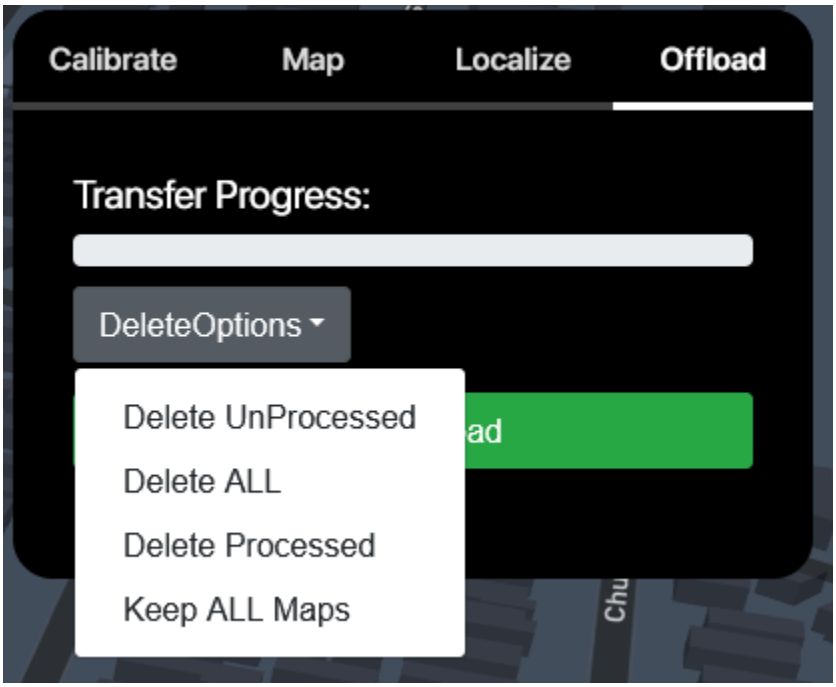

Figure 14: Option to select delete options

Uploading Data

1. If the GUI Laptop is connected to the internet during the Offload process, upload will begin automatically

2. To manually start the upload process after internet connectivity is established, launch the Uploader shortcut from the GUI Laptop

Fault Codes

A fault code is a 10-digit alphanumeric ID that indicates to the user when there is a warning or fatal fault. First digit indicates whether the code is a warning or fatal fault.

Fault Display

Warnings display on the top right of the GUI for a short period of time shown in Figure X. Fatal faults display as pop-ups in the center of the screen. When a fatal fault occurs, the system is not expected to operate at peak performance until the fatal fault has been resolved.

A summary of all the faults encountered can be viewed in the Faults panel which is displayed after selecting the *Faults* button in the top right corner of the GUI.

Fault Code Resolution Table

The following fault codes may be resolved by Magna personnel. **If a fault code occurs that is not covered in the table below, contact GPR support to resolve issue.**

Code	Message	Resolution
F_CP_00_09	Overtemperature recorded	1. Turn off vehicle 2. Turn off power to all devices 3. Contact GPR support
F_CP_00_0A		
F_CP_00_0B		
F_CP_00_0C	Over Humidity recorded	
F_CP_00_0D	Under temperature recorded	
F_CP_00_0E		
F_CP_00_0F		
F_IT_00_11	No Ublox Packets in 60 seconds	1. Check ublox has a blue light. • Ublox is located on the floor behind the center console 2. If no light on ublox, check cable on both ends (connected to ublox and middle PC in stack) 3. If light is on and fault still appears, contact GPR support
F_IT_00_12	No RTK Packets in 60 seconds	1. Check RTK is plugged in to ethernet switch. 2. Check ethernet switch has a solid white light on the right of the ports.

		• If blinking blue light, unplug and restart power on ethernet switch 3. If both conditions are met and no RTK connection, contact GPR support
W_SH_00_04	Remaining Disk space is less than 15 Gb	1. Continue with current route operations if route takes less than 30 minutes. 2. If route takes more than 30 minutes, stop operations. 3. Offload data from vehicle. 4. Upload data through Data Transfer Station.

Additional Errors

Fault codes are specifically software related. The following errors are issues that may pop up related to the user interface. **If error occurs that is not covered in table, contact GPR support for help.**

Error Message	Resolution
Calibration file is unavailable. Perform calibration to proceed	• Contact GPR to coordinate calibration
Could not establish connection with Logger PC. Raw data will not be collected for this run.	• Select “Exit” on GUI • Select “Ok” to close GUI • Open “scan” application on Desktop

Offload Error	• Check that removable drive is connected to UI PC
	  • If disconnected, connect drive to UI PC
	• Check that letter for removable drive is D:/
	  • If drive letter is incorrect, restart UI PC, and check drive letter
	• Check that any folder does not exist on the removable drive
	  • If folder exists, choose another drive which is empty and connect drive to upload station
	• Contact GPR support for more help

Please enter a map name to proceed	• Select map for localization operation
Please select a GPS device before proceeding	• Select GPS device • Complete operation

Please select a route name to proceed.	• Select route name for mapping or localization operation
Test number field contains non-numbers.	• Enter ID for mapping or localization operation
There is currently a system error. Check if all devices are plugged in & active. You can continue to try offloading, but there may be an error.	• User can try offload operation but for all other operations, follow the list below • Check that GPS devices are connected and are blinking red or solid green on the status panel in the bottom right corner of the screen • Contact GPR support for more help

There is currently no GPS devices . Please connect GPS device before mapping	• If RTK device, check NavDisplay application to make sure that the RTK device is connected
	  • If device does not show in NavDisplay, check device connection and power
	  • Contact GPR support for more help
	• If ublox device, check blue light on device
	  • If blue light is on, check device connection to embedded software PC
	  • Contact GPR support for more help

Ublox utility stopped unexpectedly	• If using ublox for localization, select “Stop Localization” and restart localization operation • If error appears during mapping, error should not impact mapping operation
Upload maps failed	• Check that drive is plugged in to UI PC • Check that folder structure is correct (ProcessedMaps → <Run Name> → gmr and db.sql files with Run Name • Switch tabs to Calibrate, Map, or Localize, select Offload tab, and retry offload operation • Contact GPR support for more help
Vehicle moving at speed greater than limits defined 110 kph	• Slow down speed during mapping operation
You must upload 2 files, a .gmre file and a .db.sql file.	• Select correct .gmre and db.sql files

Troubleshooting Guide – Frequently Asked Questions (FAQs)

SCAN GUI

Which GPS is connected to the GPR system?

- On the SCAN GUI, there is a device status section in the bottom right corner of the screen which displays each device and its status
- States for each device are as follows:
    - Grey means that the device is not communicating
    - Blinking red means that the device is communicating but is not in a good state
    - Solid green means that the device is communicating and is in a good state

Why do the GUI operations take a long time to respond?

- If the SCAN GUI initializes when the vehicle is in area with poor network connection, the SCAN GUI cannot load all the necessary files to ensure a smooth user experience
- In the event of slow response times, it is recommended to exit and restart the GUI in an area with good network connection

Why is the line of the vehicle path thin on the GUI?

- The vehicle path line may appear thinner than usual on the GUI due to the visualization utility
- In the case that the vehicle path line is too thin, simply switch the view in the top left corner to a different view and back to the original setting

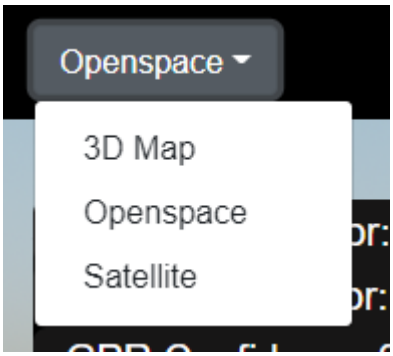

Figure 15: Options for View Settings

Why is the vehicle icon not displaying on the GUI?

- The vehicle icon may not appear on the GUI for the first 20 meters of the drive
- The vehicle icon may not appear on the GUI due to the visualization utility
- In the case that the vehicle icon is not displayed, simply switch the view in the top left corner to a different view and back to the original setting

Why does the offload operation keep failing?

- Make sure Transfer_Drive is connected
    - Make sure Transfer_Drive has the letter D as the path
- Make sure that the drive is empty
- Make sure that the connection is secure (does not disconnect intermittently)
- If error continues to occur, contact GPR support for help

Why does the loading maps operation keep failing?

- Make sure both map files (gmr and db.sql) are selected with the same name
- Make sure that the folder structure of the files is as follows: *ProcessedMaps* → Map Name → Map Name with db.sql & gmre file types
- If error continues to occur, contact GPR support for help

Why is the GPS I want not showing as a dropdown option?

- If the GPS is not showing as a dropdown option, first check the telemetry status of the desired GPS in the bottom right box of the screen
- If the GPS is green, switch tabs to another operation and come back to the tab of operation and check if the GPS is now available as an option
    - The GPS may not have been loaded on the user interface at that time
- If the GPS is RTK and solid red, refer to *Initializing RTK* section for more information
- If the GPS is ublox and solid red, check the status of the interface and if it's not *Initializing*, then contact GPR support for help
- If the GPS is grey, check the power and connection of the GPS device to the GPR system

How do I know when to calibrate?

- Calibration should occur when there is no calibration file on the vehicle

What does L_LL_##_## (fault code) mean?

- For faults that are displayed (only supported with the new GUI), refer to the *Fault Codes* section.

How do I exit the GUI if the exit button isn't working?

- Click on the Windows key on the keyboard
- Right click on the Firefox browser and close the window
- Close the command prompt that is open as well
- If restart to GUI is needed, double click on "scan" application located on the Desktop

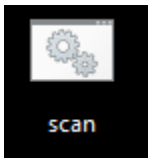

Figure 16: "scan" application to select to open GUI

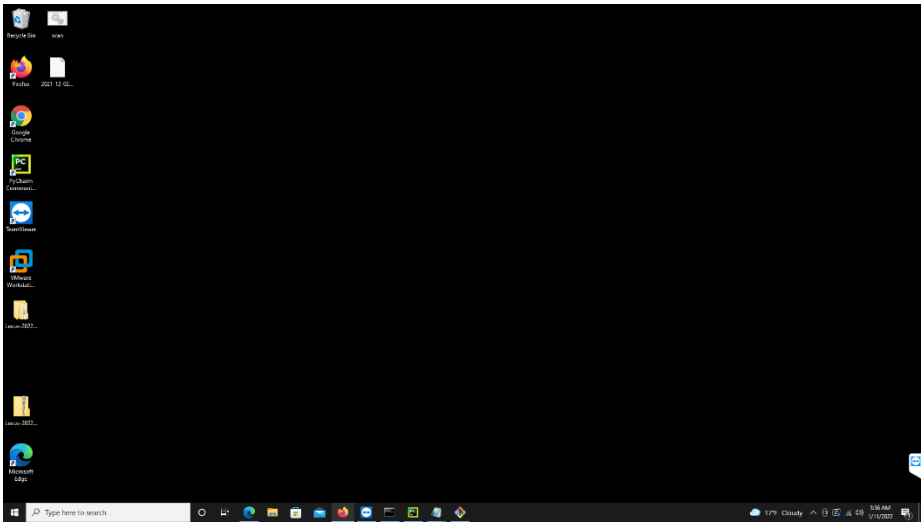

Figure 17: Desktop image

How do I know what the state of the system is?

- In the top right corner of the screen, when the SCAN interface is open, the system state is displayed
    - Initializing = system is in the process of connecting to devices and starting up
    - Ready = system is ready for operation
    - Calibrating = system is in the process of calibrating the sensor
    - Mapping = system is in the process of mapping data
    - Localizing = system is in the process of localizing to a map
    - Offloading = system is in the process of offloading data to a connected drive
    - System Error = system is in an error state

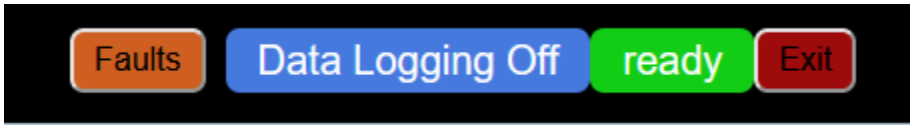

Figure 18: System state in top right corner of SCAN interface

What should I do when the Data Transfer Station fails to upload?

- If the upload process on the Data Transfer Station is interrupted, only some files will have successfully uploaded to the cloud.
- Upload process is most likely interrupted when the WiFi connection is disrupted.
- When upload process is interrupted, Data Transfer Station will display an error that needs to be acknowledged by the user.
- To retry the upload process, acknowledge the pop-up error, check the WiFi connection to ensure that it is connected, close the application, and double-click on the UploadServer application icon on the Desktop.
- Upload process will automatically restart.

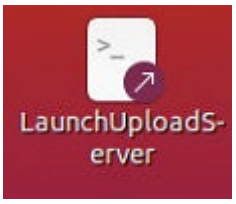

Figure 19:"UploadServer" Application located on Desktop

What should I do when the Data Transfer Station fails to download files?

- If the download process on the Data Transfer Station is interrupted,
- Download process is most likely interrupted due to a poor WiFi connection or an unplugged drive.
- Ensure that the removable drive is plugged in to the Data Transfer Station and the WiFi connection is stable.
- If retrying the download process for a map that has partial files on the removable drive, delete the folder for the intended map before retrying the downloading process.

Glossary

Calibration: Process of setting a baseline for the GPR system.

Downloading Data: Process of downloading map data from a remote location to an external drive.

Fatal Fault: An error that is critical to system performance. Error does not allow user to proceed with any further operations.

Fault Code: 10-digit alphanumeric ID to indicate a warning or fatal fault.

GUI: Stands for Graphical User Interface. Generic term to refer to any interface that is interacted with by the user.

Loading Maps: Process of transferring map data from an external drive to a GPR vehicle.

Localization: Process of positioning the GPR vehicle using previously collected map data.

Mapping: Process of collecting GPR and GPS data to generate a map.

Offloading: Process of transferring data from a GPR vehicle to an external drive.

OxTS: Company that produces ground truth devices that are used in the GPR vehicles.

Processed Map: Generated by GPR team. Improves original map with lower precision data for better localization results.

Removable Drive: Provided by GPR to Magna team to enable offloading operation on vehicle.

RTK: Stands for Real-Time Kinematic positioning. Term that is used in the company to refer to the ground truth device in the vehicle. May also be referred to as xNav550, Survey+, and OxTS.

SCAN: Also known as System Controller And Navigator. Graphical user interface (GUI) used to complete functions such as calibration, mapping, and localization.

u-blox: Automotive-grade GPS that is used during GPR system localization.

Warning: An error that is not critical to system performance. Error does not interfere with user operations.