ZEB-HORIZON
User Manual

CONTENTS

1 INTRODUCTION

The ZEB-HORIZON provides a rapid and simple means of capturing 3D point cloud data. Data is captured as the user walks through the area of interest. The ZEB-HORIZON negates the need for time consuming scanner set-ups and data registration associated with traditional terrestrial laser scanning methods.

Provided the simple guidelines set out in this manual are adhered to, accurate 3D point clouds can be generated in a fraction of the time taken with traditional terrestrial laser scanning methods.

1.1 SPECIFICATION

Maximum range	100m
Points per scan line	937 (0.38ºinterval)
Field of view	360º x 270º
Scan rate	300,000 points/s 160 lines/s (16 lines @ 10Hz)
Scan range noise	±30mm
Laser safety classification	Class 1 Eye-safe per IEC 60825-1:2007 & 2014
Laser wavelength	903nm
Operating temperature	0º C to +40º C
Ingress protection	IP54
Power supply	14.8VDC ~ 1.5A
Weight	Scanning head with handle 1.49kg Data logger 0.72kg Battery 0.55kg Carry case and contents 4.2kg
Dimensions	Scanning head 216x108x266mm (153mm excl handle) Carry case and contents 470x220x180mm
Battery life	Approximately 3 hours continuous use

Table 1-1: Specification

1.2 PRINCIPAL OF OPERATION

The ZEB-HORIZON consists of a 2D time-of-flight laser range scanner rigidly coupled to an inertial measurement unit (IMU) mounted on a motor drive. The motion of the scanning head on the motor drive provides the third dimension required to generate 3D information. A novel 3D simultaneous localization and mapping (SLAM) algorithm is used to combine the 2D laser scan data with the IMU data to generate accurate 3D point clouds.
The ZEB-HORIZON captures raw laser range measurement and inertial data. This data must be processed using GeoSLAM's SLAM algorithm to convert the raw data into a 3D point cloud. The data is processed using the GeoSLAM Hub processing application.

| Part no.	Description
1 GS_610090	ZEB-HORIZON handheld laser scanner
2 GS_610096	ZEB-HORIZON data logger
3 PAG_9307GS	ZEB-HORIZON battery
4 GS_610098	ZEB-HORIZON main cable
5 PAG_9713V	Battery charger and power supply unit
6 GS_610121	Reference base plate
7 GS_310025	USB memory stick
8 SWA_138576	ZEB-HORIZON backpack
9 OPT_8248	Data logger shoulder strap

Table 1-2: List of parts
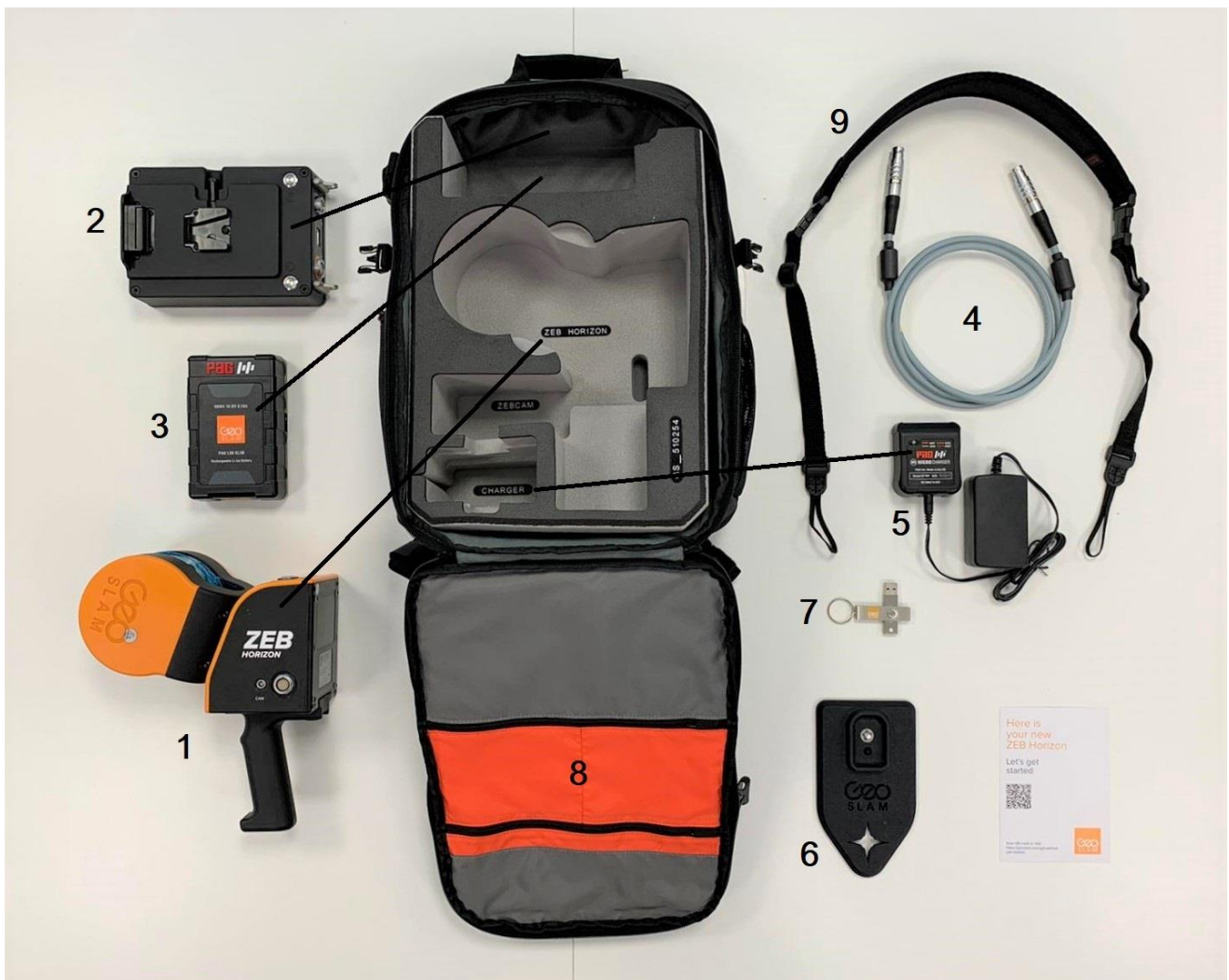
Figure 1-1

2.1   GENERAL SAFETY

The ZEB-HORIZON should only be used by trained operators. Always follow basic safety precautions when operating the ZEB-HORIZON to reduce the risk of personal injury and to prevent damage to the equipment. Do not operate the equipment with suspected defects or obvious mechanical damage. Please refer all servicing of the equipment to qualified service personnel. Only use the components and accessories supplied with your system or other accessories recommended by GeoSLAM Ltd. Before operating the system for the first time please read this manual in full.

The equipment contains sensitive electrical and mechanical parts and thus requires appropriate handling. Do not bend or pull the cables forcibly. Never push objects of any kind into the connectors or sockets. Keep the equipment out of the reach of children. Under no circumstances should any modifications be made to the ZEB-HORIZON without prior written permission from GeoSLAM Ltd.

2.2   LASER SAFETY

The ZEB-HORIZON incorporates a Velodyne Puck VLP-16 laser scanner. The VLP-16 is classified as a CLASS 1 Laser Product in accordance with IEC 60825-1:2007 & 2014. *Equipment classification and requirements.* Class 1 Laser Products are safe under reasonably foreseeable conditions of operation, including the use of optical instruments for intra-beam viewing.

2.3   ELECTROMAGNETIC COMPATABILITY

The ZEB-HORIZON meets or exceeds the following standards:

EN61326-1:2013 Electrical equipment for measurement, control and laboratory use - EMC requirements - Industrial Location Immunity - (immunity section only)

EN61326-1:2013 Electrical equipment for measurement, control and laboratory use - EMC requirements - Group 1, Class A equipment - (emissions section only)

CFR 47 Code of Federal Regulations: Pt 15 Subpart B- Radio Frequency Devices - Class A Unintentional Radiators

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. This equipment generates, uses and can radiate radio frequency energy. If not installed and used in accordance with the instruction manual this may cause harmful interference to radio communications. Operation of this equipment in a residential area may cause interference.

2.4   BATTERY SAFETY

DO NOT attempt to dismantle the battery.

DO NOT short circuit the battery.

ONLY use the charger supplied with the system.

Excess heat will degrade the battery rapidly. Always store the battery in a cool dry place. DO NOT leave for long periods in the sun or in a hot vehicle.

The battery is splash proof but not waterproof – do not immerse in water.

2.5   SYSTEM DISPOSAL

When the ZEB-HORIZON reaches the end of its life-cycle please dispose of the equipment in accordance with Directive 2002/96/EC on Waste Electrical and Electronic equipment (WEEE).

GeoSLAM Ltd is prepared to take back the waste equipment and accessories free of charge at the manufacturing unit in Ruddington, UK for proper treatment with the objectives of the WEEE.

2.6 INSTALLATION

The ZEB-HORIZON can be used as a handheld device using the supplied removable handle or can be mounted to mobile platform using threaded mounting points (see Section 7.2) or the optional mounting plate.

2.7 FURTHER HELP AND INFORMATION

In the event of a problem that cannot be resolved using the information supplied, please contact GeoSLAM. You can also gain assistance through the support page on our website: https://geoslam.com/support

For further assistance, contact GeoSLAM Technical Support by telephone or email. Our Customer Support personnel will discuss your situation, determine the cause of the problem and provide the appropriate technical assistance.

Contact GeoSLAM by any of the following methods:

- Phone: +44 (0) 1157 270740 (all countries)
- Phone: +1-833-444-7907 (US & Canada)
- Email: support@geoslam.com

3   DATA CAPTURE

This chapter describes how to connect the ZEB-HORIZON hardware, how to collect raw scan data and how to download the raw scan data from the data logger.

3.1   CONNECTING THE HARDWARE

Connect the ZEB-HORIZON main cable to the socket on the side of ZEB-HORIZON scanner head. Connect the other end of the ZEB-HORIZON cable to the REVO (orange) socket on the ZEB-HORIZON data logger. DO NOT attempt to connect the ZEB-HORIZON cable (16 pin) to the AUX socket (14 pin - with blue marker).

3.2   CONNECTING THE REFERENCE BASE PLATE

To attach the reference base plate, orientate the ZEB HORIZON and plate as shown in Figure 3-1. The base of the ZEB HORIZON handle sits within the 'cup' on the top of the reference plate and the alignment pin should be toward the front point of the plate. Fix the plate by tightening the captive screw by hand using the 'D' ring as shown in Figure 3-2 below.


Figure 3-1

Figure 3-2

The process of collecting data using the ZEB-HORIZON scanning system is highly automated. However, care must be taken to ensure that the collected data can be successfully processed into a 3D point cloud using GeoSLAM's unique SLAM algorithm. It is strongly recommended that the user conducts a survey plan, considering the recommendations set out in the Usage Guidelines in chapter 4, before commencing data collection.

When you are ready to start collecting data follow the steps in the table below:

Step 1	**Connecting the hardware:** Ensure battery is charged and connected to data logger. Connect the ZEB-HORIZON main cable to the socket on the side of ZEB-HORIZON scanner head. Connect the other end of the ZEB-HORIZON cable to the REVO (orange) socket on the ZEB-HORIZON data logger. Position the ZEB-HORIZON scanner on a flat stationary surface. Ensure the scan head is free to rotate. Turn on the ZEB-HORIZON data logger by pressing the on/off button.			
		Data Logger LED		**Scan head LED array**
		REVO	DATA	
Step 2	**Data logger booting up.**	✴ (blue)	-	-
Step 3	**Connecting to scan head.**	● (blue)	-	●●●● (blue)
Step 4	**Standby mode**	● (red)	-	●○○○ (red)
Step 5	**Initiate new scan** Long press the function button on either the scan head or the data logger until the REVO LED and scan LED array light solid red to initiate a new scan	● (red)	-	●●●● (red)
Step 6	**Initialization mode** The scan head must remain stationary for a period of 15 seconds. If the scan head is disturbed during initialisation the system will revert to standby mode (Step 4)	✴ (orange)	-	✴✴✴✴ (orange)
Step 7	**Scanning mode** After the 15 second initialization, the REVO LED and scan head LED array will light green and the scan head will start rotating. Pick up the scanner and conduct the scan.	● (green)	-	●●●● (green)
Step 8	**End scan - Data formatting** To end the scan, long press the function button on either the scanner head or the data logger until the scan head stops rotating. The DATA LED will light orange while the scan data is converted to the required output format	● (red)	● (orange)	●○○○ (red)

| Step 9 | **Standby mode**
 From stand-by either Initiate a new scan (Step 5),

 Download the data from the latest scans (section 3.3), or
 Shut down (section 3.5) | ● | - | ●○○○ |

! The scanner must remain static during initialisation

During data capture the data logger can either be carried in your spare hand, carried on your side using the supplied shoulder strap.

3.4   DOWNLOADING THE RAW SCAN DATA

To download the raw scan data, power on the ZEB-HORIZON data logger if not already powered on. Connect the supplied USB memory USB socket on the data logger front panel. The AUX LED light will light green whilst the data is transferring to the memory stick. The USB stick must not be removed when the AUX LED is lit green. After a few seconds (dependent on the size of the data files to be transferred) the AUX LED will turn off. All data that has not previously been transferred will be transferred and the USB memory stick can be removed.

! Do not remove the USB memory stick while the green AUX LED is lit

The following memory stick file formats are supported, exFAT, FAT32 and NTFS.

Downloading data is an automatic process whereby only data that has not previously been downloaded will be transferred.

Data that has been previously downloaded can be re-downloaded using the Prepare USB tool described in appendix 7.1

Files are automatically named in accordance with the start date and time of the dataset recording (with respect to the time/date set on the data logger clock) in the form *YYYY-MM-DD_hh-mm-ss*.zip

An example file name for a dataset recorded at 13:41 on 31st October 2018 is:

2018-10-31_13-41-26.zip

The system date/time can be changed using the Prepare USB tool described in chapter 7.1. The ZIP file contains two files:

*YYYY-MM-DD_hh-mm-ss***.geoslam** - file containing the raw scan data

*YYYY-MM-DD_hh-mm-ss***.params** - file containing key parameters used for data collection

3.6   SHUTTING DOWN AND LED ERROR STATUS SUMMARY

To shut the ZEB-HORIZON data logger down long press the power button until two beeps are emitted. The REVO and DATA LED's on the data logger will alternate RED until the system powers down.

! Do not turn the data logger off until the DATA LED is off.

REVO LED on data logger		LED array on scan head		Description
✳	BLUE flash	-	-	Data logger booting
●	BLUE	●●●●	BLUE	Connecting to scan head
●	RED pulse	●○○○ →	RED LED strobing from left to right	Scanner is in standby mode
●	RED	●●●●	RED	Scanner about to enter initiation mode
✳	ORANGE flash	✳✳✳✳	ORANGE flash	The scanner is in initiation mode
●	GREEN	●●●●	GREEN	The scanner is scanning mode
DATA LED on data logger				
●	ORANGE	-	-	Scan data is being formatted **! Do not turn the data logger off**
●	GREEN	-	-	Data is transferring to USB memory stick **! Do not remove the USB memory stick**

Table 3-1: ZEB-HORIZON LED status summary

REVO LED on data logger		LED array on scan head		Description
✳	Single RED flash	✳✳✳✳	Single RED flash	Laser sensor not detected
✳ ✳	Double RED flash	✳✳✳✳ ✳✳✳✳	Double RED flash	IMU sensor not detected
✳ ✳ ✳	Triple RED flash	✳✳✳✳ ✳✳✳✳ ✳✳✳✳	Triple RED flash	Laser and IMU sensors not detected
●	ORANGE	●●●●	ORANGE	Data logger turned off during Data Formatting Shut down paused until data formatting is complete

Table 3-2: LED ERROR status summary

4　USAGE GUIDELINES

This chapter provides guidelines for how the ZEB-HORIZON should be used to achieve the best possible results. Prior to conducting a survey, the user should plan the proposed survey path in order to identify potential problem areas, e.g. feature poor environments, doorway transitions and stairwells. In these areas, the user should plan how to conduct the survey taking into account the recommendations in this chapter. The plan should also make provision for "closing loops" wherever possible. Please adhere to these guidelines in order to achieve the best results.

4.1　THE ENVIRONMENT

The SLAM algorithm used to process the raw laser scan data into a 3D point cloud relies on there being features in the scanned environment that are repeatedly scanned as the operator passes through the scanned environment. For a feature to be significant the ratio of its size to its range must be approximately 1:10, e.g. at 5m range for a feature to be significant it must be >0.5m in size. 'Feature poor' environments include open spaces and smooth walled passageways. In smooth walled passageways there may not be sufficient features in the direction of travel for the SLAM algorithm to determine forward motion. In feature poor environments we recommend the following steps are taken:

- If possible augment the environment with additional features. e.g. boxes in a corridor or a parked vehicle in an open field.
- Ensure that whatever limited features are available are scanned repeatedly as you move through the environment by pointing the ZEB-HORIZON in the direction of the feature. By doing so more measurement points are made of the feature increasing the likelihood that it will be used by the SLAM algorithm. This is particularly important when the feature is at long range (>10m). e.g. when scanning a smooth walled passageway where the only feature in the direction of travel is the end wall or door.
- Avoid scanning moving objects (e.g. passing pedestrians or vehicles) as the SLAM algorithm may lock on to these objects as static features.

4.2　LOOP CLOSURE

The SLAM algorithm used to process the raw scan data into a point cloud uses a method analogous to the Traverse technique used in survey practice, in that a previously known position is used to determine its current position. This method can result in the compounding of any error introduced causing measure position to "drift". It is good survey practice to "close the loop" by re-surveying a known position so that the compounded error can be spread around the loop.

As a minimum, it is required that the operator must start and end the survey in the same position to ensure at least one loop closure. However, it is recommended where possible that the operator closes the loop as often as possible in order to minimise error and improve the accuracy of the resulting point cloud.

In general, it is better to do circular loops rather than "there and back" loops where the survey path simply doubles back on itself. This applies to horizontal and vertical loops, i.e. if possible enter and exit through different doors, move between floors via different stair wells.

It is important to scan the closed loop regions carefully to ensure the key features are scanned from a similar perspective. It may be necessary to turn around if you return to a region from a different direction. This is particularly important in feature poor environments.

4.3　TRANSITIONING BETWEEN ENVIRONMENTS

Extra care must be taken when transitioning between environments, for example passing through a doorway or turning through a tight bend to avoid introducing errors. When transitioning between environments the local view may change abruptly and the SLAM algorithm may have difficulty placing the new environment relative to the previous environment. This may result in rooms either side of a doorway being slightly misaligned.

Transition through doorways slowly and ensure that there is a period when the scanner can view features on both sides of the doorway (i.e. into both rooms).

Try to open all doors before starting the survey. Avoid scanning doors as they are being opened. If necessary, face away from the door and open from behind then pass through the doorway backwards.

Transition around tight bends slowly and ensure that there is a period when the scanner can view features on both sides of the bend.

Take care when transitioning from an enclosed feature rich environment to an open feature poor environment, for example exiting a building. It may be necessary to turn and face the exit and the exterior of the building if no other features are within range.

Avoid scanning any other moving objects (e.g. walking pedestrians) as you pass through a transition.

4.4 WALKING SPEED

It is recommended that data is captured at walking speed to ensure good coverage and high-resolution data. If the forward movement is too fast there may not be enough repeat scans of features for the SLAM algorithm to be able to process the raw laser data into a point cloud.

4.5 MINIMUM AND MAXIMUM RANGE

Data within a small range value is not processed (by default) to eliminate data from the scanner operator being included in the final point cloud. Avoid close proximity to walls and ceilings.

The maximum range of the scanner is 100m. This range will only be achieved in optimal conditions (indoors with good target reflectivity). The typical maximum range will be 60-80m in most conditions. It is recommended that the range is kept to less than 50m where possible to ensure good point density and to assist the SLAM algorithm.

4.6 DURATION OF SCANNING

For very large surveys the project should be broken down into more than one scan mission. This is to avoid very large file sizes as well as reduce any drift that might be created in the data. It is recommended that each survey is limited to 30 minutes. At slow walking pace, it is possible to cover 1000-3000m of survey distance.

4.7 SURVEY AREAS WITH RESTRICTED OR DIFFICULT ACCESS

The scanning head can remain stationary for short periods of time whilst the operator negotiates difficult access points (e.g. tight squeezes in cave systems). The scanning head can also be held in the hand and moved up and down to mimic the normal oscillating motion for short periods of time to assist transition through survey areas with restricted or difficult access.

4.8 MOVING OBJECTS IN THE ENVIRONMENT

In most case the SLAM algorithm is able to handle moving objects in the environment. In order to estimate the sensor trajectory the algorithm assumes a large proportion of the environment is static. However, in some feature poor environments where 3D structure is lacking in some dimensions, moving objects can have a greater impact on the solution. In particular, moving objects should be avoided in long tunnel-like environments (e.g. corridors), relatively open spaces and when transitioning through doorways.

It is best practice not to have other people closely accompany the operator during the scan acquisition as they will be scanned throughout the map leaving streaks of data and potentially corrupting the solution in feature poor environments. If people are required to follow the operator they should ideally maintain a distance of 20m or more from the operator.

It is necessary to process the raw data collected by the ZEB-HORIZON using GeoSLAM's 3D SLAM algorithm to generate a homogenous 3D point cloud of the environment that has been mapped. This is done using the GeoSLAM Hub processing software.

5.1   GEOSLAM HUB SOFTWARE

Installation of GeoSLAM Hub software is described in a separate User Guide.

Before the raw data can be processed is must be extracted from the zip file downloaded from the ZEB-HORIZON data logger. Copy the zip file from the USB memory stick used to download the file from the data logger to a suitable folder on the PC running GeoSLAM Hub and extract the dot geoslam file (*YYYY-MM-DD_hh-mm-ss***.geoslam**). To extract a file from a zip file right click on the zip file and select "Extract All…" from the drop-down list.

Start the GeoSLAM Hub application and drag and drop the dot geoslam file (*YYYY-MM-DD_hh-mm-ss***.geoslam**) to be processed into the "Drop datasets here to process" field on the user interface shown in Figure 5-1.
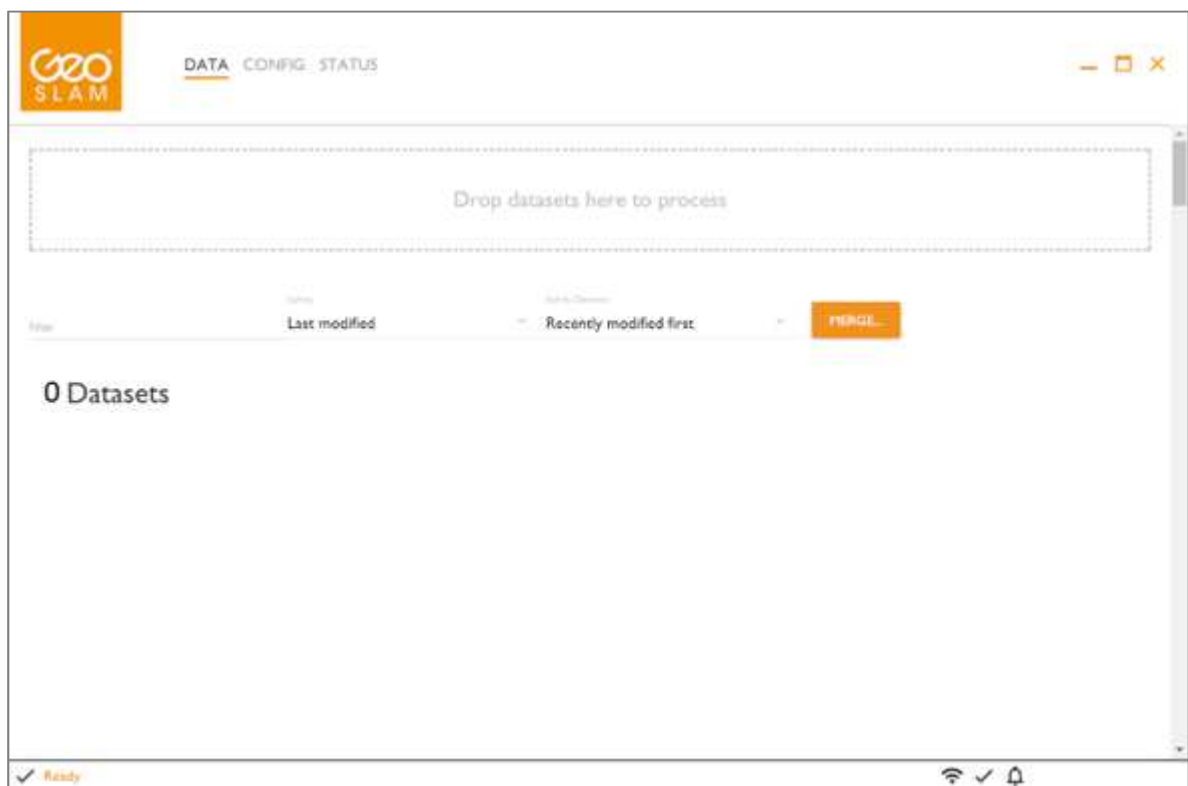
Figure 5-1

The dataset will be imported into GeoSLAM Hub and will automatically start to process. After approximately the same time it took to capture the dataset the processing of the dataset should be complete and become available for viewing and post-processing as shown in Figure 5-2.

Figure 5-2

To view the processed dataset, click the VIEW button next to the file name in the dataset list. A 3D view of the dataset opens in a new GS View window.

Figure 5-3

Further instructions for data export and the other post processing options in GeoSLAM Hub are described in the separate GeoSLAM Hub User Guide.

6.1   SPECIFICATION

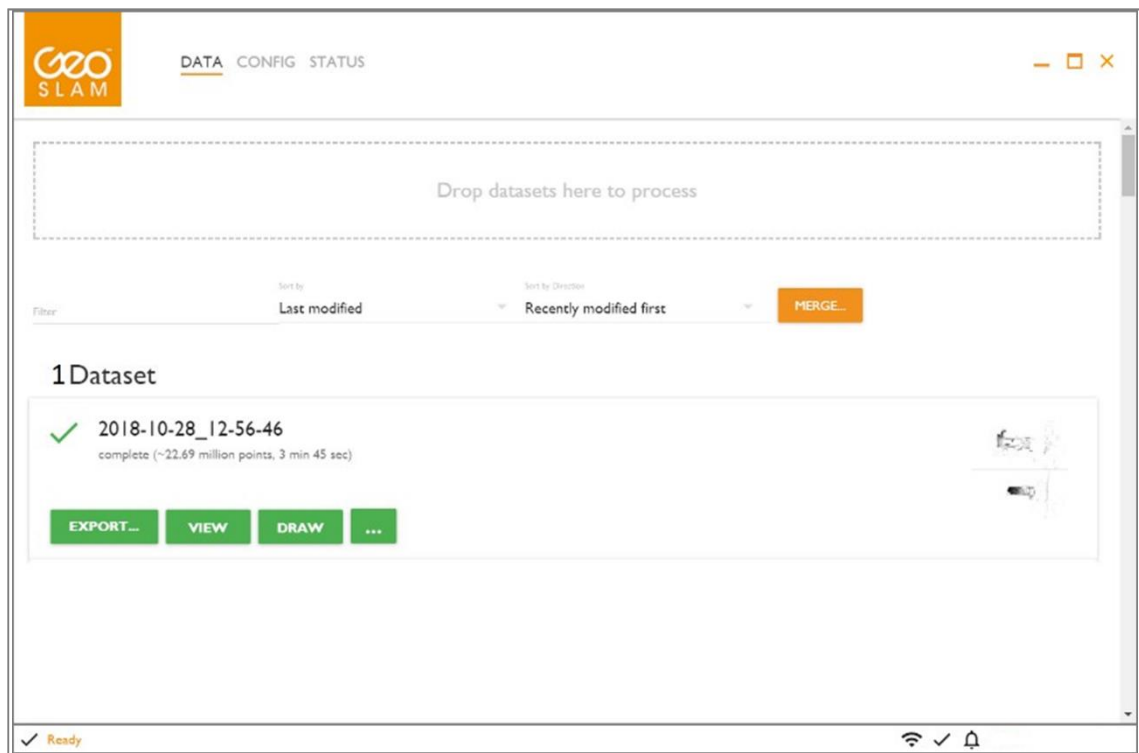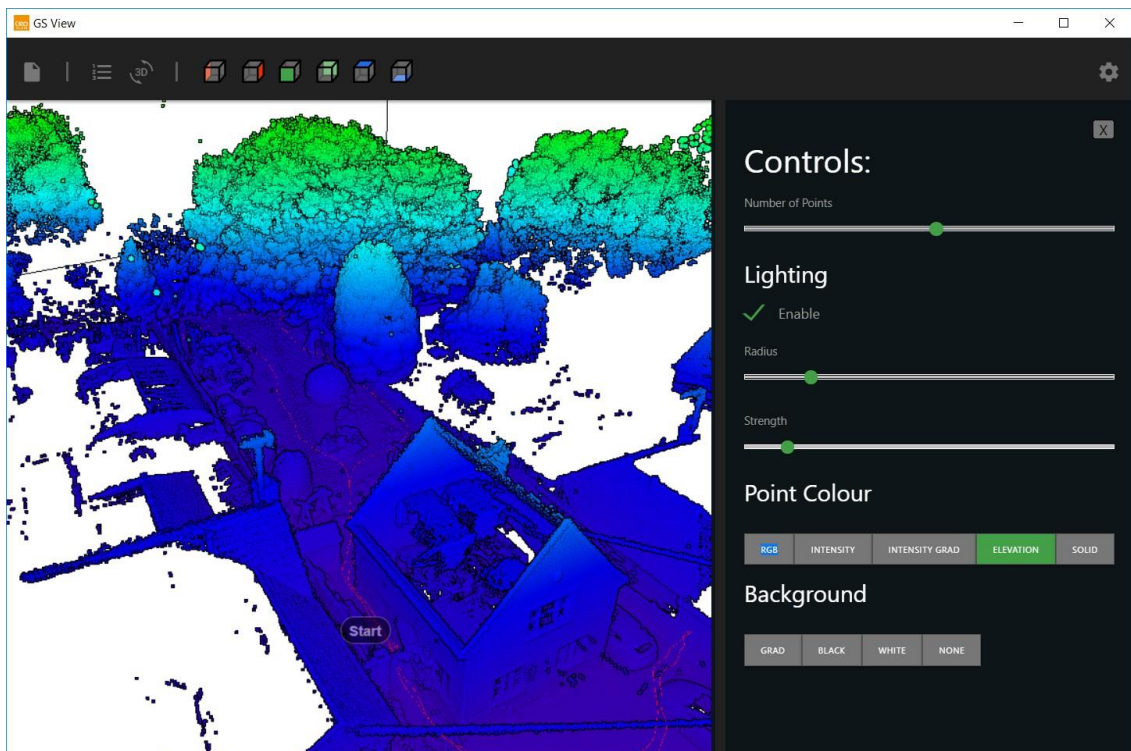| Output voltage	14.8V nominal
Capacity	6.1Ah (+/-5%) 90Wh
Charge voltage	16.8V
Weight	0.57kg
Charging temperature	0^0C to 40^0C
Life cycle	>300 cycles
Protection	Over current, over voltage, under voltage, thermal
Transportation	UN 38.3 transportation test certified

Table 6-1 Battery Specification

6.2   RECHARGING

Plug the charger into the AC mains – the LED light will glow green.

Plug the charger lead firmly into the battery the LED light will change to red to indicate charging. When

the LED light changes back to green, the battery is fully charged.

Disconnect the charger from the battery and from the AC mains.

! Do not leave the charger connected to the battery for long periods after the battery is charged.

6.3   CAPACITIY AND RUN-TIME DISPLAY

A single button press of the display button on the side of the battery shows a percentage figure of available capacity, to a resolution of 1%.

The accuracy of the display is maintained by tracking battery performance and adjusting calibration values to compensate for the ageing of the cells.

When battery is fully-discharged the display will indicate as below.

When the battery is fully charged the display will indicate 100%.

When connected to the ZEB-HORIZON that is powered on, two presses of the battery's display button will show a predicted run-time against the given load, expressed in hours and minutes.

The Capacity display senses the orientation of the battery and adjusts to ensure legibility.
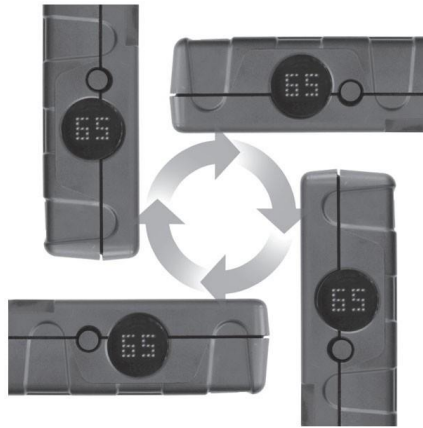
6.4 BATTERY CARE

DO NOT dispose of in normal household waste.

DO NOT attempt to dismantle the battery.

DO NOT short circuit the battery.

ONLY use the charger supplied with the battery.

The battery should be charged fully before use.

If storing the battery, store in a charged state. Recharge after every 6 months.

Excess heat will degrade the battery rapidly. Always store the battery in a cool dry place. DO NOT leave for long periods in the sun or in a hot vehicle.

It is recommended to recharge the battery within 12 hours if fully discharged.

The battery is splash proof but not waterproof – do not immerse in water.

6.5 TRANSPORTATION

The battery has been tested and passed section 38.3 of the UN Manual of Tests and Criteria (UN Transportation Testing) as required by the IATA Dangerous Goods Regulations (2016), Section 2.3.5.9. The battery is below the 100Wh limit for transportation on passenger planes. For the purposes of air transportation, the battery is classed as "Packed with equipment" (ICAO/IATA Packing Instruction 966, Section II) – Cells or batteries contained in a package with associated electronic equipment. Special rules may apply to the transportation of spare batteries. It is recommended that you check with your local air transportation safety authority and/or the proposed air carrier for specific requirements on lithium battery transportation.

Never ship a damaged battery by air transportation.

PAG Ltd.
565 Kingston Road
London SW20 8SA
United Kingdom

PAG /·/·™

Air Transport Certificate for PAG Li-Ion Batteries

PAG Ltd. London, England

hereby declares that the PAG L90 Slim Lithium-Ion battery has been tested and certified by Intertek Group PLC to comply with the UN Manual of Tests & Criteria, Part III, subsection 38.3 as required by the IATA Dangerous Goods Regulations (2016), Section 2.3.5.9.

PAG L90 Slim Battery Test Report Number: 102471069

In addition to UN testing, this Li-Ion battery has an individual Watt-hour rating below 100Wh. This rating is in compliance with the IATA DGR (2016) which states:

> *(a) each installed or spare battery must not exceed:*
> *2. for lithium ion batteries, a watt-hour rating of not more than 100Wh.*

Signed for and on behalf of PAG Ltd.

Alan Lavender

Alan Lavender
Chief Executive
Date: 01.04.16.

AIR TRANSPORT SAFE
Li-Ion
CERTIFIED
UN Test No. 102471069

7.1   APPENDIX 1 - USB PREPARE TOOL

A basic Window application called USB Prepare has been created to enable users to perform some basic interaction with the ZEB-HORIZON data logger. The USB Prepare tool can be obtained by emailing support@geoslam.com
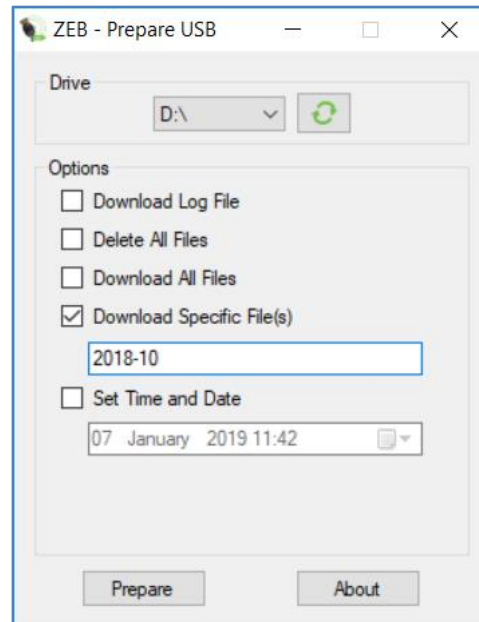

Figure 7-1

The following tasks can be performed:

- Download Log File
- Delete All Files
- Download All Files
- Download specific Files
- Set Time and Date

To perform any of the above tasks, insert a USB memory stick into a USB port on your computer and start the USB Prepare Tool. Select the Drive letter for the USB memory stick (see Figure 7-1) and check the tick box against the task you want to perform.

To **Download Specific Files,** enter the date of the required files (YYYY-MM-DD). The example in Figure 7-1 will download all data collected during October 2018.

To **Set Time and Date**, enter the required time and date.

Click **Prepare** and a small command file will be written to the USB memory stick. Eject the USB memory from the computer and attached to it to the ZEB-HORIZON data logger. Start the data logger and the requested task(s) will be performed after the data logger has booted. For the download tasks, the data will be written to the USB memory stick. If you have selected **Download All Files** a USB memory stick of at least 128GB is recommended.

1/4" 20 UNC
▽ 10 DEEP

47

82

65

4 x M4
▽ 7 DEEP

∅ 146