LiDAR Mapping Systems

Acquisition Training

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Phoenix LiDAR Systems
10131 National Blvd.
Los Angeles, CA 90034

www.phoenixlidar.com
+1.323.577.3366
support@phoenixlidar.com

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Please read carefully and visit our website, www.phoenixlidar.com for further information and contact support@phoenixlidar.com for any technical support questions.

NOTE: This document provides an overview of the basics of LiDAR acquisition with the base LiDAR mapping scanning system and relevant components. The product you purchased may not support certain functions dedicated to specific models, upgrades or customizations.

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1. Introduction

Thank you for choosing Phoenix LiDAR Systems! This document provides a brief overview and instruction of our LiDAR acquisition training for our LiDAR mapping systems. It briefly addresses the working principles of the underlying components, explains the system architecture, as well as offer a quick tutorial of the required software. If you would like a complete overview, please refer to the *Phoenix LiDAR Systems User Manual* which can be found on our homepage, www.phoenixlidar.com. This document is not intended to replace customer training; instead it should be used as an outline for LiDAR acquisition training.

Phoenix LiDAR Systems builds compact, multi-vehicle compatible, survey-grade laser mapping & photogrammetry solutions. Phoenix LiDAR products can service a range of applications such as capturing topography in open pit mining areas, power line, and railway track and pipeline inspection. Additionally, our mapping systems are equipped for terrain and canyon mapping, construction site monitoring, corridor mapping, agriculture and forestry, flood zone mapping, landslide survey and mapping, earthquake disaster mapping and much more.

2. Training Goals

The main goal of LiDAR acquisition training is to provide an overview of the use of our LiDAR mapping systems. We will address and explain the working principles of the underlying components, the system architecture, and the required software. Phoenix LiDAR Systems mapping solutions contain multiple hardware sensors that once integrated and controlled by software allow the user to create accurate, high-resolution maps of outdoor environments. Even though the accompanying software suite makes LiDAR scanning a straightforward task, the user must still understand the basic working principles of the system in order to obtain accurate data and produce quality results.

3. Software Overview

3.1 SpatialSuite

Phoenix LiDAR Systems provides a proprietary software suite for streamlined acquisition, geo-referencing, data fusion, and data export. The software suite is comprised of SpatialLightHouse and SpatialExplorer. Highlights include:

- Real-time point cloud via 3G/4G or built-in long range Wi-Fi, with patent pending real-time RGB colorization.
- Analyze LiDAR penetration and measure positions, paths and cross sections while scanning.
- Designed for multi-rotors, car, bicycle, backpack, and more.
- SDK available for real-time point cloud analytics.

The software suite can be downloaded from our website (requires authentication) and runs on any 64-bit version of Windows 8 and 10.

3.1.1 SpatialLightHouse

SpatialLightHouse allows forwarding differential corrections (satellite errors derived from raw observations) obtained from an NTRIP/CORS networked GNSS reference station to rover. Internet connectivity is required for both the computer running SpatialLightHouse and for the rover.

3.1.2 SpatialExplorer

SpatialExplorer can monitor and control the LiDAR mapping systems offered by Phoenix LiDAR Systems in real-time and replay and visualize LiDAR mapping missions in post. SpatialExplorer enables in-field quality control and analysis and ensures obtaining a quality solution throughout the acquisition process. It enables the user to calibrate camera settings without needing to rely on sending in units for “vendor-only-calibration” or adjustments. It is an exceptional tool for training with how-to-fly visualizations. Furthermore, it allows for the creation of high quality marketing imagery of acquired scans.

As a post tool, SpatialExplorer is designed to georeference data acquired by our LiDAR mapping systems into common mapping formats such as LAS/LAZ. It cuts down the wait time on extensive photogrammetry applications by creating colorized point clouds in about twice the time of the acquisition. It offers support for GNSS and INS navigation systems. Furthermore, it supports multiple remote sensing equipment configurations.

4. Hardware Overview

4.1 Rover

The rover’s hardware is pre-configured during manufacturing to facilitate the setup procedure for the end user and is comprised of four major components: PC Module, IMU (Inertial Measurement Unit), LiDAR sensor, and camera (optional).

4.1.1 Front Ports

The rover’s PC Module has a front interface panel that is designed to easily connect system components and external devices. The front panel includes Wi-Fi antenna terminal/s, UHF antenna port (optional), GPS antenna port/s, CPU power button, Sensor power button, LiDAR/IMU port, Status LED indicators, DC power input port, External Input/Output data port.

4.1.2 Rear Ports

The back panel of the PC module includes Exhaust vents, Mini HDMI port, USB 3.0 ports, LAN port, and a Mini DisplayPort.

4.2 LiDAR Sensor

LiDAR stands for Light Detection and Ranging and is a remote sensing method. It uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. Phoenix LiDAR Systems offers a variety of LiDAR sensor configurations matched specifically with the user’s mapping needs. At the time of writing, the following LiDAR sensors are supported by Phoenix LiDAR Systems:

4.2.1 Velodyne VLP-16

Laser Properties	Class 1 (eye safe), 905 nm
Range Min/Max/Resolution	1.0 m / 120 m / 2mm
RMS Ranging Error	30 mm
Scan Rate	300k shots/s, up to 600k points/s
Field of Range	±15° Vertical / 360° Horizontal FOV

Multiple Echos	2
Number of Lasers/Planes	16
Recommended Scanning Height AGL	20 - 60 m

4.2.2 Velodyne HDL-32E

Laser Properties	Class 1 (eye safe), 905 nm
Range Min/Max/Resolution	1.0 m / 120 m / 2mm
RMS Ranging Error	20 mm
Scan Rate	700k shots/s, up to 1.4 mio points/s
Field of Range	+10° to -30° Vertical / 360° Horizontal FOV
Multiple Echos	2
Number of Lasers/Planes	32
Recommended Scanning Height AGL	20 - 60 m

4.2.3 RIEGL miniVUX-1UAV

Laser Properties	Class 1 (eye safe), 905 nm
Range Min	3 m
Laser Beam Footprint	160mm x 50mm @ 100m
Max Effective Measurement Rate	100,000 meas./s
Field of View	360°
Accuracy	15 mm one Sigma @ 150m
Scanning Mechanism	Rotating Mirror
Mirror Speed	10-100 scans/sec
Multiple Echos	5

4.2.4 RIEGL VUX1-LR

Laser Properties	Class 1 (eye safe), 1550 nm
Range Min	5 m
Laser Beam Footprint	50mm @ 100m, 150mm @ 250m, 250mm @500m
Max Effective Measurement Rate	750,000 meas./s

Field of View	360°
Accuracy	15 mm one Sigma @ 150m
Scanning Mechanism	Rotating Mirror
Mirror Speed	10-200 scans/sec
Multiple Echos	7

4.3 IMU (Inertial Measurement Unit)

An inertial measurement unit (IMU) is an electronic device that measures and reports a body's specific force, angular rate, and sometimes the magnetic field surrounding the body, using a combination of accelerometers and gyroscopes, sometimes also magnetometers.

4.3.1 External IMU

At the time of writing, the following external IMUs are supported by Phoenix LiDAR Systems: IMU-32, IMU-33, IMU-34, IMU-41, and IMU-52.

4.3.2 Internal IMU

At the time of writing, the following internal IMUs are supported by Phoenix LiDAR Systems: IMU-14 and IMU-27.

4.4 Camera (optional)

The majority of the mapping solutions offered by Phoenix LiDAR Systems can be adapted to include a camera. Using a camera in conjunction with LiDAR allows the creation of an RGB colorized point cloud visualization by georeferencing the aerial photos and LiDAR data in the same reference frame, orthorectifying the aerial photos, and then draping the orthorectified images on top of the LiDAR grid. Phoenix LiDAR Systems offers support for various types of cameras including DSLR, GeniCam, GigEVision, thermal, multispectral, and hyperspectral.

4.5 GNSS Reference Station

The primary purpose of a GNSS reference station is to collect GNSS data in the form of raw observations. Raw observations are all the measurements recorded by the reference station. If you want to post-process the rover’s trajectory, raw observations from the reference station are needed.

4.6 Rover Mounting Options

Phoenix LiDAR Systems designs and develops compact and lightweight 3D laser mapping solutions for use with ground and unmanned aerial vehicles. We offer various custom solutions that are vehicle agnostic, that is they can be designed for multi-rotors, cars, bicycles, backpacks, and many more.

5. Network Configuration

5.1 Rover Static IP Addresses

Phoenix LiDAR Systems rovers are pre-configured with static IP addresses that can be reached via an ethernet or a Wi-Fi connection.

5.1.1 Ethernet

The rover's IP address on the primary ethernet interface is **192.168.200.10** or rover-wire (requires properly configured Windows .hosts file). Be aware that the rover will NOT act as a DHCP server and assign IP addresses to connected computers. Instead, the connected computer must have a valid IP address in the 192.168.200.* range configured.

5.1.2 Wireless

Rover has an integrated wireless networking card that allows it to serve as a wireless access point. The rover's IP address on the primary wireless interface is **192.168.20.10** or rover-wifi (requires properly configured Windows .hosts file). In contrast to the ethernet interface, rover will act as a DHCP server and it will assign an IP address to connected computers.

5.2 Wired Ethernet Network Card Setup

All Phoenix LiDAR Systems rovers are pre-configured with static IP addresses that can be reached via an ethernet or a Wi-Fi connection. To avoid typing in the IP addresses, field computers configured by Phoenix LiDAR Systems contain individual entries in the Windows *hosts* file that map the ethernet and Wi-Fi IP addresses to specific names, *rover-wire* and *rover-wifi* respectively.

Additionally, any computer with a properly configured ethernet adapter can be used to establish a direct connection to the rover using an ethernet cable. Field computers configured by Phoenix LiDAR Systems will default to an alternative IP configuration of 192.168.200.20 when no IP address is obtained through DHCP on the primary ethernet port within 3 minutes. This will allow a computer to establish a connection to the rover via ethernet after a connection timeout period.

6. User Laptop Configuration

If you did not purchase a base station preconfigured by Phoenix LiDAR Systems, you will need to configure your own computer to ensure it properly works with our LiDAR mapping systems.

6.1 Install Latest NVIDIA Drivers

SpatialExplorer and SpatialExplorer require that the latest NVIDIA graphics card drivers are installed on your computer. Determine the model of your graphics card and download the most recent driver from the NVIDIA Driver Downloads page.

6.2 Install SpatialSuite Software

Phoenix LiDAR Systems provides a proprietary software suite for streamlined acquisition, geo-referencing, data fusion & export. If you are using your own computer as a base station, you must install the Phoenix LiDAR Systems Spatial Software

Suite. Prior to installation, make sure you have the latest NVIDIA graphics card drivers installed. Download the latest Spatial Software Suite from our homepage. This will require user authentication. At the time of writing, the latest version of the Spatial software suite is v.3.5.1.

6.3 Install Additional Software Tools

We recommend installing the following essential software tools on your computer. If available, make sure you download the 64-bit versions:

- 7-Zip is a file archiver that will allow you to compress data files with a high compression ratio. You can use 7-Zip on any computer, including a computer in a commercial organization. You don't need to register or pay for the software.
- FileZilla is a free cross-platform FTP application, consisting of FileZilla Client and FileZilla Server. Make sure to only install the Client version (only transfer files) and not the Server version (make files available to others). You will be using FileZilla to upload any data that you wish to send us.
- TeamViewer 11 is a proprietary computer software package for remote control and desktop sharing. You must download version 11 and NOT any other version. Phoenix LiDAR Systems offers a TeamViewer Quicksupport module, which you can download from our homepage, to provide customer support. To facilitate the support process in the field, we recommend you setup TeamViewer for remote access with the password *"aeriallidar*" (no quotes).
- PuTTY is a free and open-source terminal emulator, serial console and network file transfer application that supports several network protocols, including SCP, SSH, Telnet, rlogin, and raw socket connection, as well as also connect to a serial port. Phoenix LiDAR Systems uses PuTTY to provide remote support.
- NovAtel Connect and NovAtel Convert4 allows you to access the features of a NovAtel-based reference station without the need to use a terminal emulator or write special software. At the time of writing, the latest release is ver. 2.0.1 (2017-04-21) which offers support for Windows 10.

6.4 Modify Hosts File

The *hosts* computer file is an operating system file that maps hostnames to IP addresses. It is a plain text file. It serves the function of translating human-friendly hostnames into numeric protocol addresses, called IP addresses that identify and locate a host in an IP network. The contents of the hosts file is used preferentially with various name resolution methods, one such being the Domain Name System (DNS).

To modify the *hosts* file in Windows 8/10, open Notepad as an administrator (right-click on Notepad, hover over the *More* option, and click on *Run as administrator*). If you have User Account Control (UAC) enabled, click Yes to allow Notepad to open with administrative permissions.

Navigate to the folder *C:\Windows\System32\drivers\etc* and locate the *hosts* file. If necessary, select the option to view "All Files (*.*)" to display the *hosts* file. Click on the *hosts* file and click the *Open* button.

With the *hosts* file open, enter the following two entries at the end of the file, each on their own separate line:

```
192.168.200.10 rover-wire
192.168.20.10 rover-wifi
```

Save the *hosts* file and close Notepad.

6.5 Wired Ethernet Network Card Setup

You must configure a Windows 8/10 computer with an alternative IP address. This will enable your computer to connect to the rover via ethernet when no IP address is obtained through DHCP on the primary ethernet port within 3 minutes.

In Windows, open up the Control Panel and navigate to Network and Sharing center. Click on “Change adapter settings” located near the top, left-hand side of the window and identify the primary ethernet adapter in your computer. Right-click on the primary ethernet adapter and select “Properties” Click and select “Internet Protocol Version 4 (TCP/IPv4)” and click on “Properties.”

Click on the alternate configuration tab and select the “User configured” option. Enter the IP address *192.168.200.20* in the IP address field box and subnet mask address *255.255.255.0* in the Subnet mask field box. Click “OK” and then “Close” the ethernet adapter properties.

Your computer should now have an alternate IP address configured.

7. Connect to Rover

7.1 Connect via Ethernet

The rover's IP address on the primary ethernet interface is **192.168.200.10**. Be aware that the rover will NOT act as a DHCP server and assign IP addresses to connected computers. Instead, the connected computer must have a valid IP address in the 192.168.200.* range configured.

If you want to test your settings, you can do so by accessing the rover’s **\logs** directory. Connect an ethernet cable from rover to your computer. Wait approximately 3 minutes, and connect to **\\192.168.200.10\logs** with the username **“phoenix”** (no quotes) and password **“aeriallidar”** (no quotes). Alternatively, if you have configured the *hosts* file, you can connect to **\\rover-wire\logs**. Same username and password.

7.2 Connect via Wi-Fi

When the rover is powered on, it will create its own Wi-Fi network named “phoenixXXX”, where XXX are the first three digits of the rover’s serial number. The wireless security password is **“aeriallidar”** (no quotes). Any number of devices can connect to this network, receiving an IP address in the 192.168.20.X subnet through DHCP.

7.2.1 Bullet Long Range Wi-Fi Module

To establish a strong wireless connection between your laptop and rover, you must use the Bullet Long Range Wi-Fi module. It is a wireless radio with an integrated Type N RF connector that can be directly plugged into either the included omnidirectional or directional pad antennas. Includes the ram mount, a 20 ft ethernet cable, and an ethernet data+power adapter.

The Bullet Long Range Wi-Fi module is configured to automatically connect to the rover’s wireless access point. Remember to attach the included 5.8 GHz Wi-Fi antennas to the rover’s WLAN terminals. The rover creates an internal 802.11b Wi-Fi network on Channel 1 at 2.414 GHz, which has a maximum raw data rate of 11 Mbit/s. If the 5.8 GHz antennas are not attached to rover, you will notice a significant decrease in signal quality and strength.

Setup is simple and straightforward. Connect the ethernet end of the ethernet data+power cable to the ethernet port on the laptop. If your laptop does not have an ethernet port, use a USB to ethernet adapter. Connect a Li-Po battery to the EC5 end of the power adapter. When powering the Bullet Long Range Wi-Fi module, we recommend using a **4 cell Li-Po** battery.

If you want to test your settings, you can do so by accessing the rover's **\logs** directory. Once connected to the rover's Wi-Fi network, connect to **\\192.168.200.10\logs** with the username **"phoenix"** (no quotes) and password **"aeriallidar"** (no quotes). Alternatively, if you have configured the *hosts* file, you can connect to **\\rover-wifi\logs**. Same username and password.

7.3 Connect via Phoenix LiDAR Systems Connection Service

The Phoenix LiDAR Systems Connection service allows for communication between SpatialLightHouse/SpatialExplorer and rover via a remote online server. Communication is established through an alphanumeric License Key that is uniquely assigned to each rover. An internet connection is required on both the computer running SpatialLightHouse/SpatialExplorer and rover for this to function. While in the field, we recommend connecting your laptop to a dedicated mobile hotspot; rover requires an external USB cellular modem, preferably a compatible 4G USB modem. Rover will automatically connect to the remote server upon establishing a connection to the internet.

8. Reference Station

8.1 Hardware Overview

The primary purpose of a GNSS reference station is to collect GNSS data in the form of raw observations. Raw observations are all the measurements recorded by the reference station. If you want to post-process the rover's trajectory, raw observations from the reference station are needed.

8.1.1 CHC X900+

The CHC X900+ GNSS receiver leverages the latest GNSS technology by integrating 120 channels with the ability to track GPS, GLONASS, Galileo and Beidou and field software dedicated to topographic and construction surveying. Features include:

- Future proof 120-channel core GNSS with the ability to track GPS, GLONASS, Galileo and BeiDou
- High performance GNSS RTK positioning covering wide range of applications
- Integrated Bluetooth, GPRS and radio modem
- Innovative and rugged design built for harsh environment
- Ability to configure via SpatialLightHouse (via Bluetooth or Serial to USB connection)

8.1.2 Stonex S900

The Stonex S900 features a new, high accuracy multi constellation antenna, a powerful UHF transmitter and the GSM 4G modem, for a fully integrated communications choice, combined with a light and modern design. The integrated GNSS receiver tracks all the present constellations and satellite signals GPS, GLONASS, BEIDOU, GALILEO and QZSS and through the upgradable firmware offers the opportunity to be day by day updated with the latest available features.

- 555 channels provides an excellent on board real time navigation solution with high accuracy
- All GNSS signals (GPS, GLONASS, BEIDOU and GALILEO) are included, no additional cost

- Web UI Control to initialize, manage, monitor the settings of the receiver and to download data using a laptop or PC, smartphone or tablet with Wi-Fi capability
- Dual slot for two Smart hot swappable batteries gives you up to 12 operating hours
- IP67 certification combined with a high shock resistance guarantee the maximum strength and the best water and dust tight even in harsh environments

8.2 Equipment Setup

We recommend mounting the GNSS reference station antenna with a clear view of the sky, away from buildings and powerlines.

★ **When applying power to the CHC X900+ GNSS reference station, make sure to ONLY use a 4 cell Li-Po battery.**

You must mount the GNSS reference station onto a survey-grade tripod, composed of either wood, aluminum, or fiberglass. To prevent any discrepancies when measuring the Antenna Reference Point (ARP) height, we recommend a fixed height survey grade tripod. This will ensure a uniform measurement throughout all scanning missions.

8.3 Connection Methods

8.3.1 CHC X900+

The two primary methods of communicating with a CHC X900+ GNSS reference station are through a Bluetooth connection or through a USB/Serial connection (a Serial to USB adapter is required if your laptop lacks a dedicated serial port). If using Bluetooth, you will be required to pair the GNSS reference station with your laptop.

Alternatively, you can set it to manually log upon pressing a button or auto log based on a minimum number of satellites.

8.3.2 Stonex S900

The Stonex X900 can be set to manually log upon establishing a connection through the Web UI Config. Alternatively, it can be set to log automatically based on a minimum number of satellites.

9. SpatialLightHouse

9.1 Connect to a Private Reference Station

When using a private, physical reference station in the field, select the "Use Private ReferenceStation" tab. You must configure several parameters to ensure that SpatialLightHouse properly collects data from the reference station.

9.1.1 Connection Methods

9.1.1.1 Bluetooth

You can configure a supported GNSS reference station connected via Bluetooth through SpatialLightHouse. If you are pairing a CHC X900+ via Bluetooth in Windows 8/10, the passkey is **1234**. Additionally, you must take note of the **OUTGOING** Bluetooth COM port; the Outgoing COM port will allow SpatialLightHouse to communicate with the CHC X900+.

9.1.1.2 Serial/USB

Connect to the reference station via serial or via Serial to USB. When this option is selected, the COM port is automatically selected in SpatialLightHouse.

9.1.2 Supported Models

Below is a list of the GNSS reference stations currently supported by SpatialLightHouse. You must select one of the options below. If your GNSS reference station model is not listed below, then you must choose the “Generic (Passthrough)” option.

The Generic (passthrough) option assumes that you have pre-configured your non-supported reference station to allow external communication either through Bluetooth or Serial/USB communication. Be aware that when the Generic (passthrough) option is selected, the options to configure the reference station are disabled.

- Generic (passthrough)
- Leica GS14
- NovAtel
- CHC X900+Bluetooth
- CHC X900+Cable (10-Pin LEMO to USB/RS232 serial port cable)

9.1.3 Configure Position

If you’ve selected a GNSS reference station model other than “Generic (passthrough)”, you must select this checkbox to manually configure the position of the GNSS reference station as well as the output method of communication between the rover and the reference station. This option is only enabled if a GNSS reference antenna model other than “Generic (passthrough)” is chosen.

9.1.3.1 Average Position

This will configure the reference station to measure its own position for a preset amount of time if accurate georeferencing is not required or is not possible. It will accept the average of those measurements as its own position. The position will only be accurate to the submeter after a few hours of averaging, therefore the produced map will not be accurately georeferenced. Furthermore, the reference station will not emit differential corrections before it has finished averaging measurements.

9.1.3.2 Known Position

This will configure the reference station’s position, more specifically the position of the antenna phase center, over a known, precise point in WGS84 datum. GPS uses a height system that measures height from the WGS84 ellipsoid model of the earth.

- **Reference Station Height:** This interface will help you calculate the height of the reference station when measured from the surface of the WGS84 ellipsoid to the L1 phase center. This measurement is a summation of three separate height calculations.

```
Applied Height = (H. of Marker above WGS84 Ellipsoid) + (H. of ARP above Marker) + (H. of L1 Phase Center above ARP)
```

SpatialLightHouse uses nine decimal places to measure both Latitude and Longitude. You may have coordinates with greater than nine decimal places, however we have determined that nine decimal places allows for more precision than is necessary.

9.1.4 Configure Output

9.1.4.1 UHF

Enabling the UHF radio button will configure the GNSS reference station to send differential corrections via the integrated UHF modem. The option to change the frequency at which the UHF modem will transmit data is disabled unless you provide a password. Due to legal constraints, Phoenix LiDAR Systems will issue a password to the frequency coordinator of your organization. In most countries, a license is required to transmit in the UHF spectrum.

9.1.4.2 Serial Port

This will configure the GNSS reference station to emit differential corrections via the serial port if supported. This will allow any custom hardware (i.e. an external radio modem) to connect to the primary serial port.

9.2 Connect to a Public Reference Station

When using a public reference station, select the “Use Public ReferenceStation (NTRIP)” tab. You must configure the parameters correctly to ensure that SpatialLightHouse properly collects data from a public correction network in the form of streams. A stream is usually a combination of reference station and differential corrections data.

NTRIP Caster	The hostname or IP address of the NTRIP caster.
Port	The port number of the NTRIP caster, Default value is 2101.
Username	The user name for the NTRIP caster account.
Password	The password for the NTRIP caster account.

Click the “Fetch Sources” radio button to retrieve a list of available streams from the NTRIP caster.

9.3 RTK (Real Time Kinematic)

SpatialLightHouse can forward differential corrections (satellite errors derived from raw observations) obtained from the GNSS reference station to the rover. The rover can then apply these errors to its own measurements using a technique known as Real-Time Kinematic.

Real Time Kinematic (RTK) is a satellite navigation technique used to enhance the precision of position data derived from satellite-based positioning systems (global navigation satellite systems, GNSS) such as GPS, GLONASS, Galileo, and BeiDou. It uses measurements of the phase of the signal's carrier wave, rather than the information content of the signal, and relies on a single reference station or interpolated virtual station to provide real-time corrections, providing up to centimetre-level accuracy. RTK allows the rover to solve its own position in real-time to within centimeter-level accuracy.

9.4 Connect to Rover

SpatialLightHouse offers various methods upon which differential corrections can be forwarded to rover. The two most common methods of forwarding differential corrections are as a TCP client and through the Phoenix LiDAR Systems Connection Service.

Be aware that SpatialLightHouse must remain connected (either through Bluetooth or USB/Serial) at all times to the GNSS reference station to forward differential corrections. Additionally, SpatialLightHouse must be running throughout the entirety of the scanning mission to successfully forward differential corrections to rover.

9.4.1 TCP Client (ethernet/Wi-Fi)

You can forward differential corrections to rover via an ethernet or Wi-Fi connection by providing either the hostname or IP address of the rover. A connection can be established via an ethernet cable (using the hostname ***rover-wire*** or the IP address ***192.168.200.10***) or by connecting to the rover via Wi-Fi (using the hostname ***rover-wifi*** or the IP address ***192.168.20.10***).

9.4.2 Phoenix LiDAR Systems Connection Service

SpatialLightHouse will send differential corrections to a remote online server. This requires an internet connection on the computer running SpatialLightHouse. We recommend connecting the computer running SpatialLightHouse to a mobile hotspot and rover to a compatible 4G USB modem. Rover will automatically connect to the same server and retrieve the corrections. The correct License Key must be entered for the server to correctly associate the current session of SpatialLightHouse and rover.

9.5 Start Session

Press the "Start" button to initiate data processing. Depending on the configuration, SpatialLightHouse will connect to the reference station, configure it, connect to rover, and forward differential corrections.

If the Start button is grayed out, this indicates that the current configuration is not supported. Here’s how to fix it:

- Check that all required fields are filled.
- When using a serial port to connect to the reference station, if the port does not appear in the list, restart SpatialLightHouse. Available ports are only scanned once on startup, therefore make sure the selected port is listed as free, not busy. A busy port is currently in use by other programs.
- When using the option "Provide differential corrections on a serial port", make sure the selected serial port is not the same port as the port used to connect to the reference station.
- When using NTRIP make sure a stream with supported differential correction format is selected. If the stream requires authentication, make sure the username and password values are populated.
- When using the Phoenix LiDAR Systems connection service, make sure the license key is valid (indicated by a green checkmark).

10. SpatialExplorer

10.1 Connection Methods

10.1.1 Work Offline

When launching SpatialExplorer in offline mode, you will not be able to view data or configure sensors in real-time, however you will be able to load and analyze your post-mission georeferenced point-cloud data.

10.1.2 TCP Client (ethernet/Wi-Fi)

Launching SpatialExplorer as a TCP client allows you to establish a real-time connection to rover either through ethernet or Wi-Fi. You must select the “Connect to rover as a TCP client (WiFi or ethernet)” option. All Phoenix LiDAR Systems rovers come preconfigured with a default hostname for both Wi-Fi or Ethernet connections. A connection can be established via an ethernet cable (using the hostname ***rover-wire*** or the IP address ***192.168.200.10***) or by connecting to the rover via Wi-Fi (using the hostname ***rover-wifi*** or the IP address ***192.168.20.10***). In order to connect to the rover via Wi-Fi, the laptop running SpatialExplorer and the rover itself must be connected to the same wireless network.

10.1.3 Phoenix LiDAR Systems Connection Service

Select this option to connect to rover through the Phoenix LiDAR Systems connection service. The correct License Key must be entered for the server to correctly associate the current session of SpatialExplorer and rover. We recommend connecting the computer running SpatialExplorer to a mobile hotspot and rover to a compatible 4G USB modem. Rover will automatically connect to the Phoenix LiDAR Systems connection service server upon successfully detecting an internet connection.

10.2 Work Offline

10.2.1 Open Files

In order to view the data contained within the data files generated by the rover during a scan, you must first load them into SpatialExplorer. This can be done by using the File menu near the top right corner of SpatialExplorer, navigating to File → Open file. Alternatively, you can press the keyboard shortcut CTRL + O.

The dialog window will prompt you to load a.plp file. Once the plp files has been loaded, the trajectory data along with the initial system status data is displayed. SpatialExplorer allows viewing important system and mission values such as system voltage and temperature (only when using .nav files), or navigation system data like the vehicle's position and orientation, solution accuracy or the number of satellites tracked.

To view the recorded point cloud in real-time in SpatialExplorer version 4.0.X and below, you must hit the Play button located in the bottom right corner of the Playback Menu. You can select the “Step” option to forward the scan to the first instance of either GNSS, LiDAR, or Camera data. To access the Step option menu, right long-click the Step button and select your option. During playback, you can choose which sensors (camera, LiDAR, etc.) are activated in the main display area by toggling them from within the Sensors window.

10.2.2 Local Settings

SpatialExplorer provides customization of local and rover (when connected to rover) parameters. You can configure default local settings, such as language or visualization settings, or you can configure default rover settings, such as antenna offsets and IMU orientation.

The General settings in SpatialExplorer allows for the configuration and customization of various parameters including Language, Units, and Visualization. The Visualization section allows the user to customize the various parameters relating to the projection of point clouds and photos within the main viewing window.

Of importance in the Visualization section is the “Maximum Point Cloud Size” option. This controls the maximum amount of points that will be displayed in the main viewing window during playback. If at any point the limit is reached, SpatialExplorer

will delete points displayed during the beginning of playback to make room for upcoming points. This does not affect the number of points captured during a real-time scan. The .ldr file itself is not modified in any way.

10.2.3 Windows

The System Monitor window displays various system parameters (Pose, GNSS/INS, Statistics) relating to the rover and sensors during playback.

The Sensor Controller window allows you to toggle the available cameras and sensors during playback. You can choose which sensors to display by toggling them ON/OFF during playback.

- **Camera**: Allows you toggle the different options for the camera sensor. When using raw images taken with a DSLR, you must first convert them to JPG, TIF, or PNG before SpatialExplorer display them. Raw images from Basler cameras are automatically decoded. You must place the converted JPG images in the *camX/* folder. This will ensure that SpatialExplorer is able to properly load the images.

SpatialExplorer Work Offline Camera Sensor Options	
OFF	Virtually deactivates the camera sensor.
PRV	Displays and overlays above the point cloud a preview of the images captured during scanning.
FSE	Fuses color captured from the images into the point cloud.
P&F	Preview and overlay above the point cloud the images captured and fuse color from the images into point cloud.

- **LiDAR:** Allows you toggle the different options for the LiDAR sensor during playback.

SpatialExplorer Work Offline LiDAR Sensor Options	
OFF	Deactivates the LiDAR sensor.
ACT	Activates the LiDAR sensor and displays the point cloud in the main viewing window.

10.2.4 Map Layers

The Project window displays the different types of layers available. You can use layers to control the type of information displayed in the main display area. To enable or disable a layer, click the checkbox next to the name of the layer. SpatialExplorer allows customization of the Pointclouds map layer. Simply right click on the desired point cloud layer and you will be presented with a pop-up menu where you can change various display parameters such as Point Size, Colorization, Intensity, etc.

10.3 Real-Time

10.3.1 Windows

10.3.1.1 System Monitor

The System Monitor window displays various system parameters relating to the rover and sensors in real-time. The types of parameters monitored are Pose (latitude/longitude, roll/pitch/yaw, etc.), GNSS/INS (PosStatus, UncertaintyP, CorrAge, etc.), and Statistics (Packets, Points, etc.)

Embedded within the System Monitor window is the Commands window which displays a list of available commands that you can send directly to the rover. The main command is “Shutdown Rover”; this command will end the connection between rover and SpatialExplorer. There is a designated text box that will allow the user to enter any notes; the notes will be saved as a text file in the rover’s log directory. Additionally, you can select to power off rover’s onboard computer (essentially powering down rover) as well as force a shutdown of the system.

10.3.1.2 Sensor Controller

The Sensor Controller window allows you to toggle the available cameras and sensors in real-time. You can choose which sensors to display by toggling them ON/OFF during playback.

- **LiDAR**: Allows you toggle the different options for the LiDAR sensor during your scan.

SpatialExplorer Real-time LiDAR Sensor Options	
OFF	Deactivates the LiDAR sensor.
SLT	Activates the LiDAR sensor, but does not display the point cloud in the main viewing window.
ACT	Activates the LiDAR sensor and displays the point cloud in the main viewing window.

- **Camera**: Allows you toggle the different options for the camera sensor.

SpatialExplorer Real-time Camera Sensor Options	
OFF	Deactivates the camera sensor.
SLT	Activates the camera sensor, but does not display the photo preview frustum in the main viewing window.
ACT	Activates the camera sensor and displays the photo preview frustum in the main viewing window.

10.3.1.3 Measurements

The Measurements window allows you to perform various measurements on the active map layer. Depending on which map layer is selected, points can be picked from the point cloud layer, the trajectory layer, or other additional map layers. To clear the points from the Measurements window, click the radio button labeled “Clear” located in the right bottom corner. Furthermore, clicking on the Time entry will step the Log Player to that specific time.

The POS option will identify the position of a point anywhere on the active map layer. It will extract the X, Y, and Z coordinates of any point as well as the capture time. You can add multiple points into the Measurements window.

The PTH option will measure the path distance between sequential points anywhere on the active map layer. To define a path, a minimum of two points are required. The path length is measured sequentially; this means that the length is calculated by adding the previous path length to the next path length.

The PRF option will generate a horizontal profile section view of the points in a cloud as defined by a path created anywhere on the active map layer. The depth of the profile can be altered in the bottom right corner of the Measurements window (this is only visible when the PRF option is selected). Alternatively, you can use the POS tab (as long as two points are selected) and switch over to the PRF tab. This is a useful tool to view the distance between each point in the cloud.

10.3.2 Rover Settings

There are multiple rover parameters that can be configured via SpatialExplorer.

10.3.2.1 Navigation System

There are various navigation system parameters located within this tab. Of importance is the “Orientations & Offsets” section which includes IMU to GNSS antenna offsets, IMU orientation, and Vehicle/Body rotation.

Each time the system is re-mounted on a vehicle, or the IMU or antenna is moved on the vehicle, the IMU to GNSS offsets (also known as lever arm measurements) must be redefined through manual measurement. The measurements do not have to be exact; these are estimates of the measurements as defined by the limits imposed by the uncertainty values. Before performing a scan, you must ensure that you have the correct offset measurements from the IMU’s center of navigation to the GNSS antenna L1 phase center. These measurements will be your IMU to GNSS antenna offsets. The orientation of the IMU and the vehicle/body rotations are required to obtain a successful INS alignment.

10.3.2.2 LiDAR Sensor

This interface contains the configuration parameters for your LiDAR sensor. In most cases, we recommend not altering these values unless instructed to do so.

10.3.2.3 Camera Sensor

This interface contains the configuration parameters for your Camera sensor.

11. Field Scanning

11.1 Reference Station Setup

11.1.1 Equipment Setup

- ❏ The first thing you want to set up in the field is your GNSS reference station.
- ❏ Make sure to document the Antenna Reference Point (ARP) height above the ground.
- ❏ Provide power to your GNSS reference station. **If using a CHC X900+ GNSS reference station, make sure to ONLY use a 4 cell Li-Po battery.**

11.1.2 SpatialLightHouse Configuration (CHC only)

- ❏ Set up a portable computer and connect it to the GNSS reference station via Bluetooth or USB/Serial communication. If using USB/Serial, make sure to use a USB to RS-232 DB9 Serial Adapter. If communicating via Bluetooth, determine which COM port is the Outgoing port.
- ❏ Launch SpatialLightHouse and choose the appropriate method of communication between your laptop and the GNSS reference station. In most cases, you'll be communicating over **USB/Serial**. Make sure to select the correct **outgoing** COM port in SpatialLightHouse.
- ❏ Choose the correct "Model." This will allow you to edit the Position/Outgoing configuration parameters. If you are using a GNSS reference station that is not supported by SpatialLightHouse, make sure to choose the "Generic (passthrough" option and that you have configured your reference station to transmit data through your connection method of choice (Serial or Bluetooth).
- ❏ If using a reference station supported by SpatialLightHouse, select the "Configure Reference Station (Position/Output)" checkbox and configure the reference station to average its own position (Average Position) or over a known point (Known Position). Configure the Output (UHF or Serial Port) method if you will be transmitting differential GPS data to rover.
- ❏ To transmit differential corrections to the rover, you can select as **TCP client** with the Rover Hostname as **rover-wifi** if using Wi-Fi or via the **Phoenix LiDAR Systems connection service** if using a 3G/4G cellular connection.
- ❏ Press the "Start" button to initiate data processing. Depending on the configuration, SpatialLightHouse will connect to the reference station to configure it. Additionally if you chose to forward RTK it will connect to rover, and forward differential corrections

11.2 Proper Scanning Procedure

11.2.1 IMU to GNSS Antenna Offsets

It's important to ensure that your IMU to GNSS antenna offset measurements are within an appropriate range before initiating a mapping mission. If these measurements are not within an acceptable range, it will cause a mismatch between uncertainty values (position and attitude), which will make it difficult to obtain a proper IMU alignment solution. Before powering on rover, we recommend verifying the IMU to GNSS antenna offset measurements.

1. Locate the GNSS antenna L1 Phase center and the IMU center of navigation. The location of the antenna L1 phase center can be found in the antenna's datasheet, while the IMU center of navigation is displayed on the IMU/enclosure label.

2. Measure the distance from the IMU center of navigation to the GNSS antenna L1 phase center along each axis of the IMU and record the measurements.

To compare your measurements with the entered values in rover you need to power on rover and connect through SpatialExplorer; open the *Orientation & Offsets* settings in SpatialExplorer located in *Settings → Rover → Navigation System*. There is an uncertainty value that determines the standard deviation of each measurement. Therefore, your measurements are considered estimates. If you choose to post-process your trajectory, you will have the option to update each IMU to GNSS antenna offset measurement with a more accurate value. Always verify your measurements before updating them in SpatialExplorer. Make sure to restart rover if you update the IMU to GNSS antenna offset values.

11.2.2 Static/Kinematic Alignment

Before initiating a LiDAR mapping mission, you must align your IMU (Inertial Measurement Unit). This is an EXTREMELY important procedure and CANNOT be skipped. The type of alignment technique you must perform will depend on the type of IMU included with your system. Rovers with IMUs of tactical grade or higher are capable of static alignment. Rovers with MEMS IMUs, or any IMU with a gyro bias larger than the Earth rate of 15 deg/hr at the equator, are not capable of deriving a reliable heading from gyro measurements alone, therefore they must rely on kinematic alignment.

At the time of writing, the IMUs supported by Phoenix LiDAR Systems that allow for static alignment are the IMU-32, IMU-33, IMU-34, IMU-41, and IMU-52. The IMUs supported by Phoenix LiDAR Systems that require kinematic alignment are the IMU-14 and IMU-27.

If your system is capable of static alignment, you must leave the system powered on and idle at its departure site for a period of about 5-10 minutes in order to obtain a reliable static alignment. During this time, the system will determine its heading and the navigation system status (INS) in SpatialExplorer will switch from ***Aligning*** to ***AlignmentComplete***. Static alignment uses the average of the sensor output, therefore *it is imperative for the vehicle to remain completely stationary for the duration of the alignment*.

If your system includes an IMU not capable of static alignment, the default alignment routine is kinematic alignment. During kinematic alignment, the navigation system status (INS) will read ***Aligning*** until movement is detected. To achieve ***AlignmentComplete***, we recommend travelling forward for a period of at least 10 seconds, at a minimum velocity of 5 m/s (18 km/h), moving as straight and as level as possible with an unobstructed clear line of sight. This will kinematically align the navigation system. You will notice the navigation system status (INS) in Spatial Explorer switch to “AlignmentComplete.” indicating that the heading has been determined with sufficient certainty.

11.2.3 Figure Eights

In order to achieve an INS status of ***SolutionGood***, you must conduct two to three sets of figure-eights, either manually or using waypoint mode to stabilize the navigation system. This allows the software to process the current IMU drift and noise. We recommend flying a figure eight pattern because it helps lower the covariances (Uncertainty Position and Uncertainty Attitude), which are estimated errors of position and attitude.

11.2.4 Activate/Deactivate Sensors

After achieving an INS status of ***SolutionGood*** and low covariance values (approximately 0.0090 or less for both UncertaintyP and UncertainityA), you can activate the sensors (camera, LiDAR, etc.) within SpatialExplorer and begin scanning your flight. We highly recommend flying straight to obtain smooth scan lines throughout the scan area. Furthermore, avoid sharp turns and extreme elevation changes, and turn only at the perimeter of your scan area. Using

autopilot will result in the best scan results. Data acquired during turns will be much less accurate. Once you've finished scanning your flight, deactivate the sensors from within SpatialExplorer.

11.2.5 Mirror Beginning and End Procedures

Before landing, if you intend to post-process the trajectory for increased accuracy, you must conduct another two to three sets of figure eights then travel forward for a period of at least 10 seconds, at a minimum velocity of 5 m/s (18 km/h), moving as straight and as level as possible with an unobstructed clear line of sight.

If possible, end the mission from the same place it was initiated. Before shutting down rover, you must turn the LiDAR sensor OFF (if you have a Velodyne sensor, LONG press the sensor button on rover; if you have a RIEGL sensor, shut down the LiDAR sensor through SpatialExplorer).

If your rover is capable of static alignment, leave the rover static for a period of about **5-10 minutes** to allow the IMU to obtain a reliable static alignment. During this period, the IMU must be completely static. Otherwise, if your rover relies on kinematic alignment, you can proceed to shut down the rover using the "Shutdown Rover" radio button in SpatialExplorer. Alternatively, you can SHORT press the CPU button on the system. However, be aware that shutting down rover this way will result in a forced shutdown.

We recommend mirroring the same procedures during the beginning and end of a scan to help increase the accuracy of your processed trajectory in NovAtel Inertial Explorer. During trajectory post-processing, NovAtel Inertial Explorer calculates the best trajectory solution by processing the data in various directions: forward, reverse, or both. When the software's algorithm processes both directions, it helps to have similar procedures at beginning and end of scan to obtain the best solution.

12. Download Data

12.1 Rover Data

After you've finished scanning, you must download the data from rover to your computer/server. The rover's IP address on the primary ethernet interface is **192.168.200.10**. Be aware that the rover will NOT act as a DHCP server and assign IP addresses to connected computers. Instead, the connected computer must have a valid IP address in the 192.168.200.* range configured.

To download data you must access the rover's **\logs** directory. Connect an ethernet cable from rover's ethernet port to your computer. Wait approximately 3 minutes, and connect to **\\192.168.200.10\logs** with the username **"phoenix"** (no quotes) and password **"aeriallidar"** (no quotes). Alternatively, if you have configured the *hosts* file as instructed, you can connect to **\\rover-wire\logs**. Same username and password.

Once you've accessed the **\logs** directory, locate the folder containing your desired data. Folders are named with the following naming scheme: YEARMONTHDAY-UTCTIME (e.g. 20170802-210846). You may find numerous folders inside the **\logs** directory. Everytime rover is powered on it creates a folder named with a corresponding timestamp. To locate the correct folder/s, we recommend sorting the **\logs** directory by descending *date modified* and searching for the most recent folders containing LiDAR files (.ldr or .rxp). Once you've located the folders with the desired data, copy (DO NOT move) the data to a location of your choice on your computer. We recommend creating a folder on your desktop to temporarily store the data.

Once the data has been copied, you can close the **\logs** directory window. Access the copied data on your desktop and create a new folder named **rover** inside the folder containing the data. Move the contents of the folder inside the newly created **rover** folder. This will allow you to organize all your original rover data in one place. Repeat this procedure for any remaining data sets you copied from the **\logs** directory.

If you want to retrieve data from the rover, we recommend **NOT** using the rover's Wi-Fi connection. The rover creates an 802.11b Wi-Fi network on Channel 1 at 2.414 GHz, which has a maximum raw data rate of 11 Mbit/s. Because of the slow transfer rate, we recommend that you do not attempt to download any data from the rover with Wi-Fi; the resulting data transfer will take an immense amount of time to complete. If you need to transfer data from the rover to your computer, **ALWAYS** use the ethernet connection.

12.2 GNSS Reference Station Data

To download data from the CHC X900+, power on the CHC X900+ and connect the USB cable located on the end of the LEMO power/data cable to your computer. Do not use the Serial to USB adapter. The CHC X900+ will act as an external hard drive and should pop up in Windows. Locate the folder containing your desired data. Folders are named with the following naming scheme: YEARMONTHDAY. Access the folder and copy the corresponding file containing the raw observations in .HCN format. You will need to convert the HCN file to RINEX.

The method you use to download data from your GNSS reference station will differ by model. At the time of writing, Phoenix LiDAR Systems only offers support for the CHC X900+. If you decide to use your own GNSS reference station, make sure the final format of your raw observations are in RINEX format.

12.3 DSLR Images (optional)

When using RAW images taken with a DSLR, you must manually download them from the DSLR's SD card onto your computer and convert them to JPG, TIF, or PNG before SpatialExplorer and SpatialExplorer can use them. Raw images from Basler cameras are automatically decoded. We recommend using Sony's Image Data Converter to convert RAW images to JPG or TIF.

You must place the converted DSLR JPG images in the ***camX/*** folder (usually CAM0 if you only have one camera) found within the **rover** folder that you created when downloading rover data. This will ensure that SpatialExplorer and SpatialExplorer are able to properly load the images.

13. Inspect Data

With rover, GNSS reference station, and image data downloaded onto your computer, we recommend you inspect the acquired data in SpatialExplorer. Launch SpatialExplorer in "Work Offline" mode. While in offline mode, you will not be able to view data or configure sensors in real-time, however you will be able to load and analyze your post-mission georeferenced point-cloud data.

14. SpatialExplorer (Post)

14.1 Load Trajectory Data

SpatialExplorer requires that you load an initial Phoenix LiDAR Project (.plp) file in order to process data. After opening the .plp,, SpatialExplorer will search the plp's root directory for other data files from LiDAR sensors and cameras and automatically add those files to the project.

Once the plp has been loaded, you can add a post-processed trajectory to the project. SpatialExplorer supports the following trajectory file formats:

.nav	Unprocessed, low-rate real-time trajectory data computed during scanning..
.POF/.POQ	Riegl's post-processed high-rate trajectory data that contains absolute time. Manually exported from a NovAtel Inertial Explorer loosely-coupled or tightly-coupled trajectory.
.OUT	SBET (**S**moothed **B**est **E**stimate of a **T**rajectory) high-rate trajectory data. Manually exported from a loosely-coupled or tightly-coupled trajectory processed by NovAtel Inertial Explorer. Only contains Time-of-Week information, therefore the correct GPS week and time system has to be specified when opening the file.
.cls	**C**ombined **L**oosely-coupled **S**moothed trajectory. Native high-rate post-processed trajectory created by NovAtel Inertial Explorer starting with version 8.70. Contains absolute time and does not lead to ambiguities as to which solution (loosely-coupled or tightly-coupled) the file was exported from.
.cts	**C**ombined **T**ightly-coupled **S**moothed trajectory. Native high-rate post-processed trajectory created by NovAtel Inertial Explorer starting with version 8.70. Contains absolute time and does not lead to ambiguities as to which solution (loosely-coupled or tightly-coupled) the file was exported from.

14.2 Configure Sensors

You can configure the numerous parameters associated with the sensors or cameras from this interface.

14.2.1 LiDAR Sensor

The Acquisition tab displays several measurement parameters related to the LiDAR sensor. These parameters include the hostname of the device containing the sensor, the rotational velocity of the sensor, the rotation of the sensor after scanning, and the return mode as well.

The Calibration tab displays the Transforms for the sensor with respect from the center of the IMU to the center of the LiDAR sensor. The *Translation* fields define the offset from the center of the IMU to the LiDAR's optics. The *Rotation (extrinsic ZXY order)* fields define how the LiDAR sensor is oriented relative to the IMU. These values should not be altered unless necessary, and only then should be used in very special cases.

The Processing tab displays several parameters that can filter the point cloud acquired in real-time based on several parameters. Such fields allow changing the LiDAR's downward FOV and reflectance scale.

14.3.2 Camera

Calibration fields allow changing the Camera's calibration values, such as sensor size (in mm), pixel size (in px), as well as camera position and camera orientation. These options should not be altered unless necessary, and only then should be used in very special cases.

The Acquisition tab of the camera sensor allows you to view but not change the camera sensor's technical settings. You can inspect the Event Pin of the camera as well as the method of Triggering.

The Processing tab allows you to set the options for LiDAR colorization such as the Color Storage Channel for both LAS and RealTime. Furthermore, it allows you to set the number of photos that should be used for LiDAR colorization of each point.

14.4 Export to LAS

The Export to LAS option allows you to configure the various parameters associated with exporting the data into common mapping formats such as LAS or LAZ.

14.4.1 Output Directory

This is the directory where SpatialExplorer will place the fused LAS or LAZ file. The default output directory is the same as the directory that houses the loaded trajectory file.

14.4.2 Output Coordinate System

When you add a trajectory file to SpatialExplorer, it will automatically determine the correct coordinate system. However, if you want to change the output coordinate system you can do so from within SpatialExplorer by clicking the "..." radio button located to the right of the Output Coordinate System indicator.

From the Select Coordinate Reference System window, you can search for a Coordinate System or you can select a Coordinate System from the available list.

14.4.3 File Type

SpatialExplorer supports two LiDAR file types: LAS and LAZ. A LAS file is an industry-standard binary format for storing airborne lidar data. LAZ files are basically just compressed versions of LAS files. The advantage of a LAZ file is a smaller file size useful for storing and transferring data.

14.4.4 Time Format

SpatialExplorer supports various time formats. We recommend using Time of Week (seconds) as your time format. Seconds of the week will allow you to easily match the point cloud records with the time in the SBET when calibrating in Terrasolid. This will allow you to connect the point cloud with the trajectory based on time. If you choose any other time format, then the alternate time format would be stored in the LAS/LAZ file instead of Time of Week (seconds), but you will encounter difficulty in post-processing when calibrating the point cloud along with the trajectory.

14.4.5 Point Source ID

The Point Source ID option allows you to associate each point in a cloud with its corresponding laser of origin. Much like each the X, Y, and Z coordinate values or the R/G/B values, the Point Source ID is a property of every point in a LAS/LAZ file.

When you create a LAS/LAZ file from a multi-laser LiDAR sensor (e.g. Velodyne VLP-16, Velodyne HDL-32E) and you inspect a single point, you will not be able to identify which specific laser created that specific point. However, if you associate the ID number of each laser (e.g. 0-15 for the Velodyne VLP-16 or 0-31 for the Velodyne HDL-32E) into the Point Source ID of each point, then you will be able to identify which specific laser created each point. This option is useful during post-processing after exporting with SpatialExplorer; it allows the calibration of every laser in a multi-laser LiDAR sensor.

When setting the Point Source ID, there are several options to choose from: Zero, Index of Interval, Index of Laser Head (Multilaser) or Deviation (Riegl), Index of Laser Log. The following table describes the available Point Source ID options:

Zero	Sets the Point Source ID value of all points to 0. A Point Source ID of zero implies the points originated in this file at some time during processing.
Index of Laser Head (Multilaser)	Sets the Point Source ID to match the index as indicated by the layout of the lasers in the LiDAR sensor.
Index of Laser Log	Associates the Point Source ID values based on individual LiDAR log files. The Point Source ID value will begin with index 0 with every new LIDAR file generated.
Index of Interval starting at 0	Sets the Point Source ID value to match the index as indicated by the corresponding flight intervals (e.g. 0, 1, 2, 3, etc.)
Index of Interval starting at 1, with all curves set to 0	Sets the Point Source ID value to match the index to 1 as indicated by the corresponding flight intervals, while setting the index of all points acquired in curves to 0 (e.g. 1, 0, 2, 0, 3, 0, etc.)
Deviation (Riegl)	Sets the Point Source ID to use the pulse shape of the echo signal which is compared to the pulse shape representing the system response.The pulse shape deviation can be interpreted as a comparison of the area below the shape curve.
Amplitude (Riegl)	Sets the Point Source ID to use the amplitude of the echo signal reaching the laser scanner. The value of the amplitude reading is a ratio, given in the units of decibel (dB).

14.5 Tools

14.5.1 Convert Time

SpatialExplorer features an integrated time converter tool. It will convert from any one time format to multiple time formats. Time formats include UNIX, GPS, UTC, UTC Day, GPS Week, and GPS TOW (time of week).

14.5.2 Convert Images

Raw images from Basler cameras are automatically decoded. SpatialExplorer has a built-in image converter located in the Tools menu bar, *Tools → Convert Images* to convert raw images only from Basler cameras for your own use (e.g. loading them into Pix4D or PhotoScan).

14.5.3 Edit Camera Events

The Edit Camera Events option in SpatialExplorer provides a detailed list view of the position and time metadata of all the images in the project. From this interface, you can refine the poses of the images with a post-processed trajectory (only available if a post-processed trajectory has been loaded).

Additionally you can add a filename to each image by associating each image to an event. Upon clicking the “Load image filenames”, you will be prompted to select the images you wish to associate with events. You can select one or multiple images. Once you select the images, you will be asked to specify the position in the table where you will be placing the first tile, default value is 1. This is especially useful if you need to import an image list into Agisoft PhotoScan; PhotoScan will not let you import an image list unless each image contains a filename. SpatialExplorer allows you to add a filename to each event. You will need to export the current camera receptor file as a .csv for use in Agisoft Photoscan.

You can also remove camera events from with the “Remove Single Event” button. Removing camera events destroys the association between images and events.

14.5.4 Overwrite EXIF Orientation

The EXIF specification defines an Orientation Tag to indicate the orientation of the camera relative to the captured scene. This can be used by the camera to indicate the orientation automatically with an orientation sensor. SpatialExplorer allows the user to indicate the orientation manually without actually transforming the image data itself via the “Overwrite EXIF Orientation” option.

Before proceeding you must backup the images. Any changes to the EXIF orientations will be permanent. We highly recommend making a copy of the *camX* folder before proceeding.

14.5.5 Convert Velodyne .ldr to PCAP

This option allows you to convert a Velodyne .ldr file to a de facto standard network packet capture file format called a .pcap file. Many publicly available Velodyne HDL packet captures use this PCAP file format as a means of recording and playback.

14.5.6 Convert Velodyne PCAP to LDR

This option allows you to convert a .pcap file to a .ldr file. You can obtain .pcap files from Network Packet Analyzer Programs such as Wireshark which is available for most platforms, including Linux, MacOS and Windows.

14.5.7 Plot Trajectories

The Plot Trajectories option allows you to load and compare several real time trajectories. This is useful for debugging and comparing trajectories. Simply load as many trajectories you wish to compare and it will display the data of each graph on one single plot interface.

This content is subject to change.
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If you have any questions about this document, please contact Phoenix LiDAR Systems by sending a message to support@phoenixlidar.com.