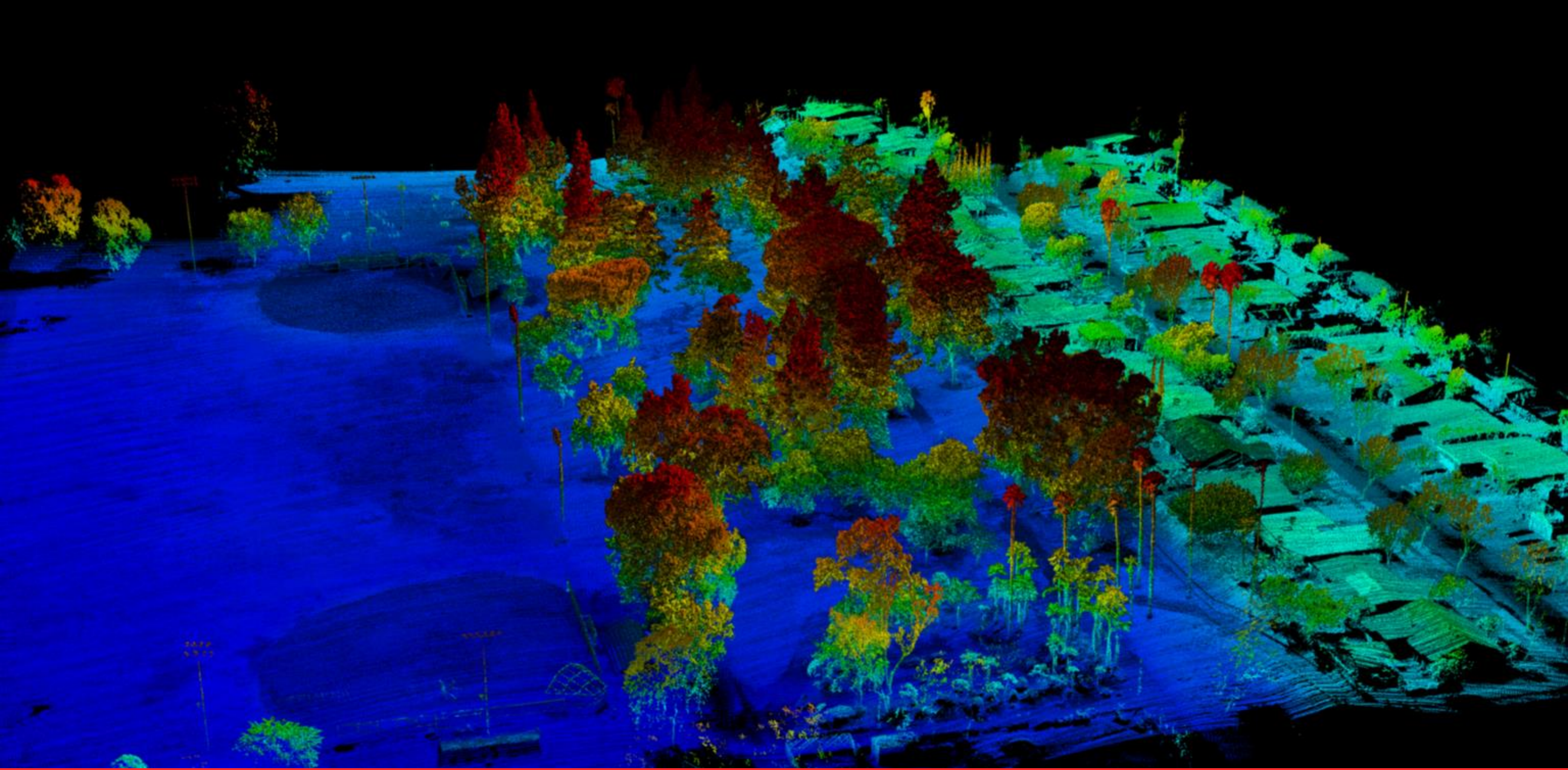
PHOENIX
LiDAR SYSTEMS

ACQUISITION TRAINING

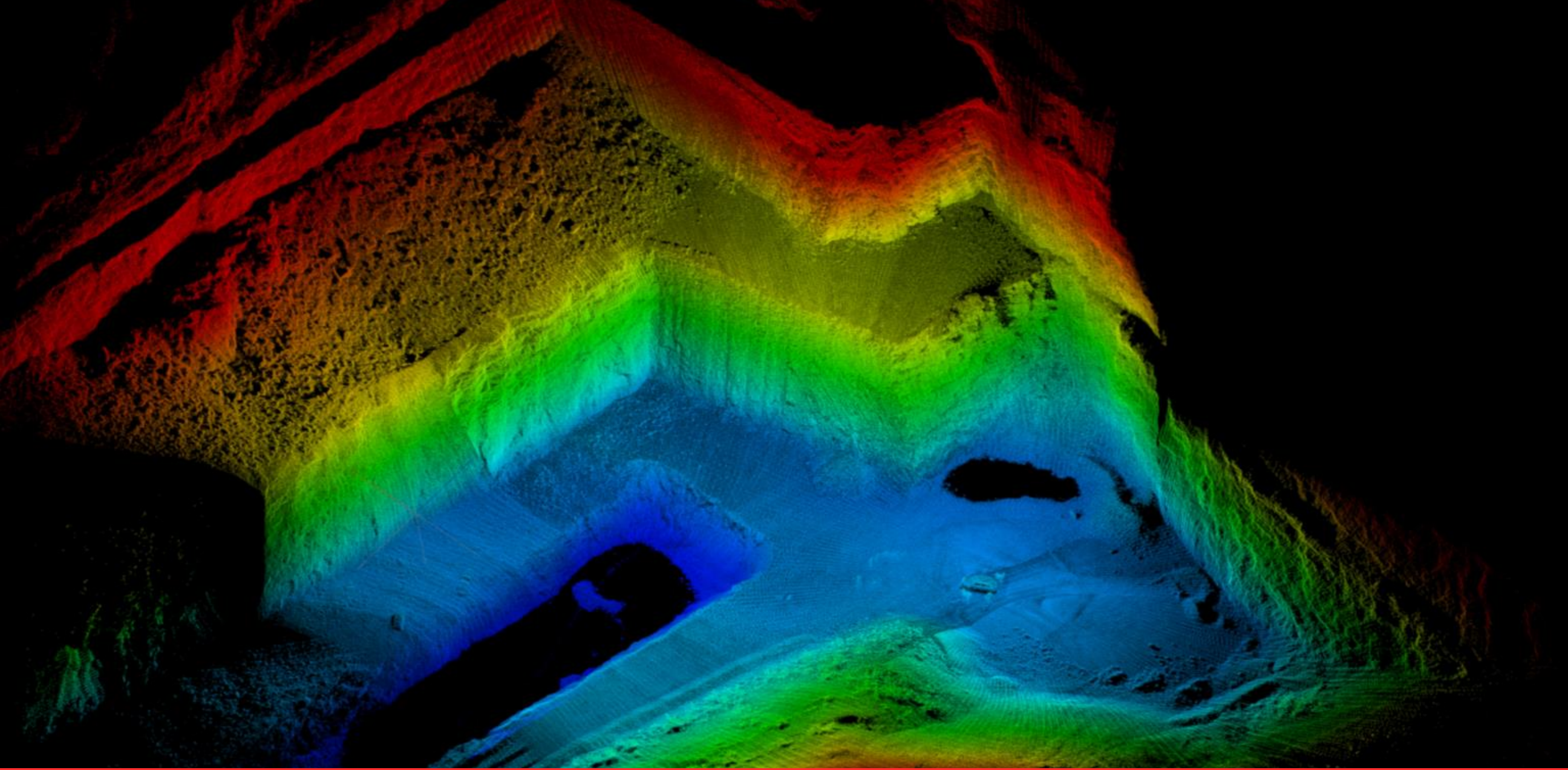
Compact, multi-vehicle compatible, survey-grade laser mapping & photogrammetry solutions.

Service a range of applications:

- Capturing topography in open pit mining areas, power line, railway track and pipeline inspection.
- Terrain and canyon mapping, construction site monitoring, corridor mapping, agriculture and forestry.
- Flood zone mapping, land slide survey and mapping, earthquake disaster mapping and much more.



PHOENIX LiDAR SYSTEMS



PHOENIX LiDAR SYSTEMS

Acquisition Training Goals

- Provide an overview in the use of our LiDAR mapping systems.
- Address and explain working principles of components, system architecture, and required software to understand the basic working principles of the system in order to obtain accurate data and produce quality results.
- Understand how the integration of multiple hardware sensors controlled by software can be used to create accurate, high-resolution maps of outdoor environments.

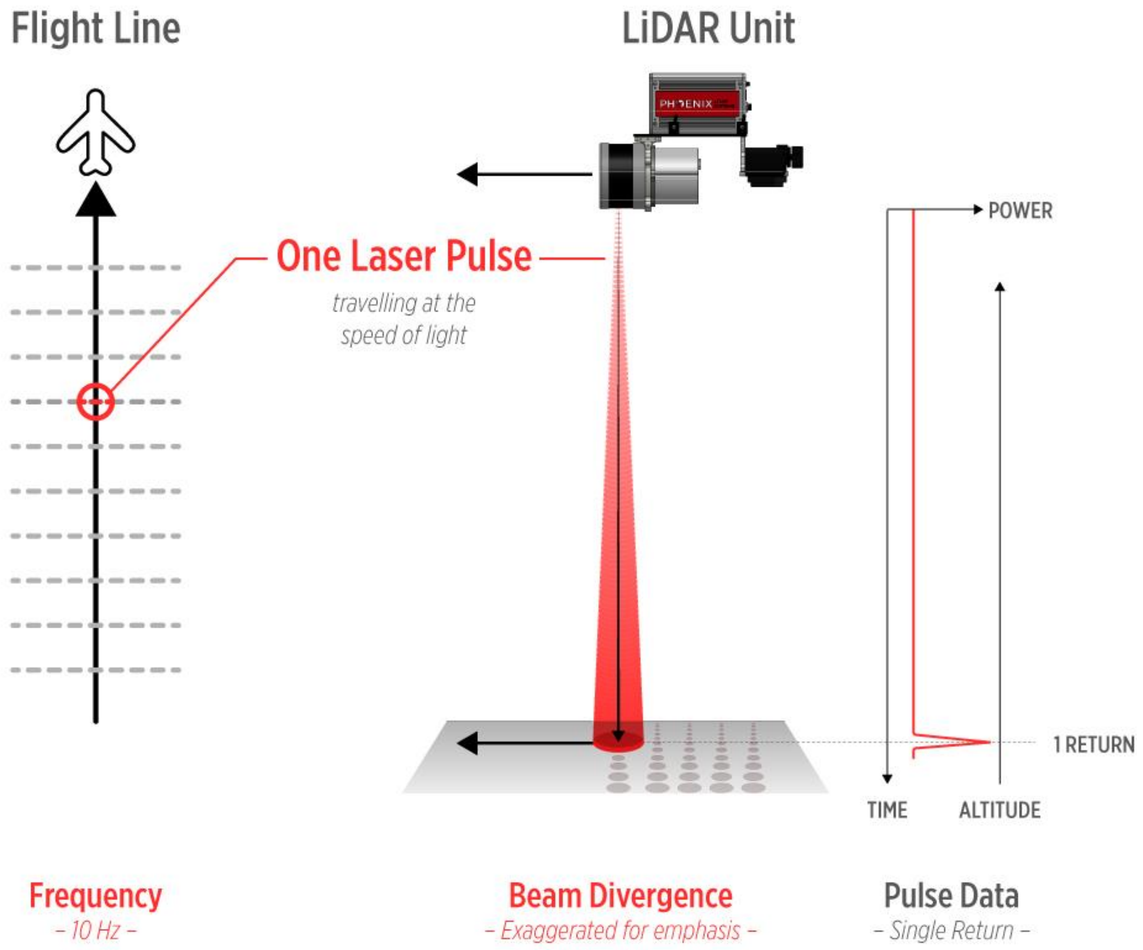
What is LiDAR?

- LiDAR stands for Light Detection and Ranging, and is a remote sensing method.
- Uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth.
- These light pulses, combined with other data recorded by a system, are processed to create highly accurate, three-dimensional information about the surface it has scanned.

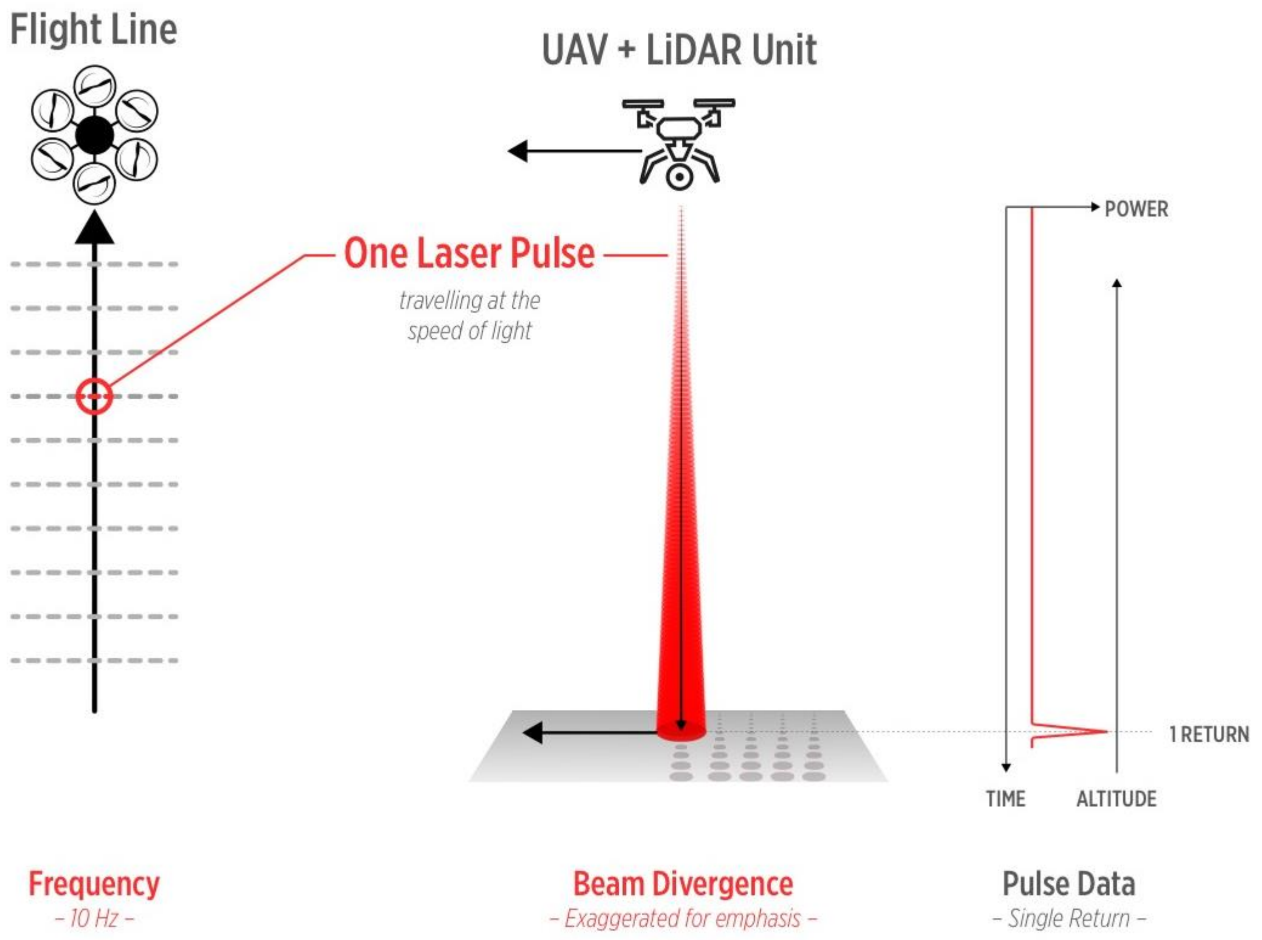
What is LiDAR?

- A LiDAR instrument principally consists of a laser, a scanner, and a specialized GPS receiver. Phoenix LiDAR Systems builds topographic, multi vehicle compatible solutions.
- This particular type of LiDAR uses an eye-friendly near-infrared laser to map the land and cannot scan through water or other high reflective materials.
- Data applications include obtaining ground scans without vegetation, density and volumetric measurements, RGB color-fused point clouds, thermal imaging and more.

What is LiDAR?

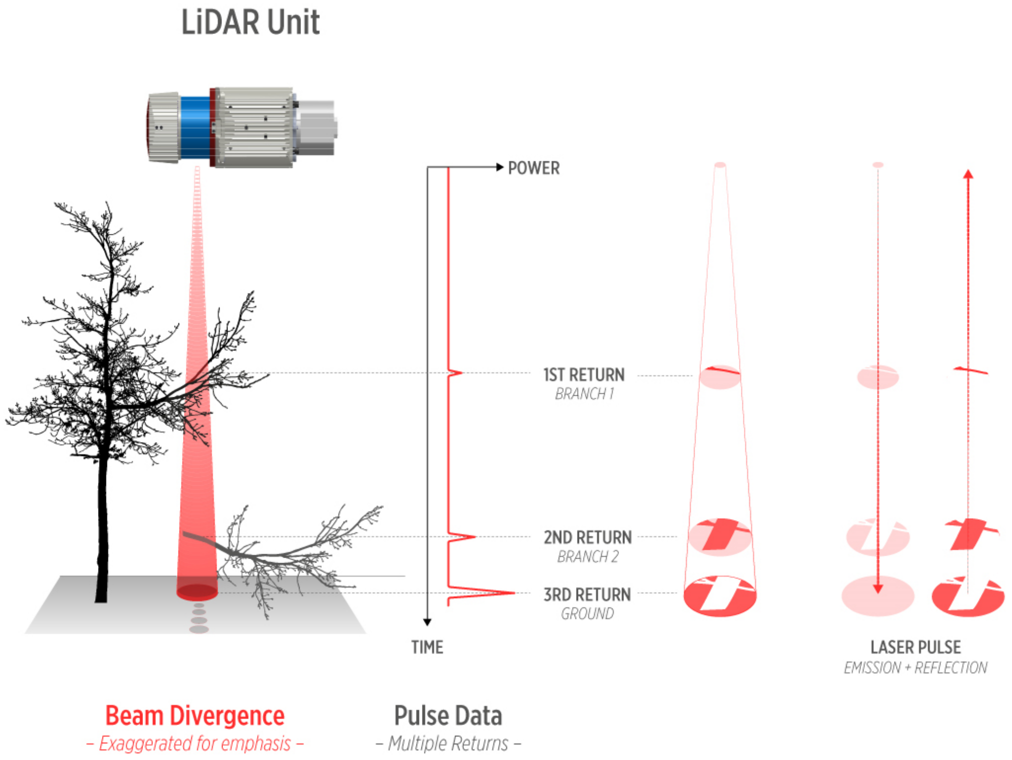


Basics of LiDAR

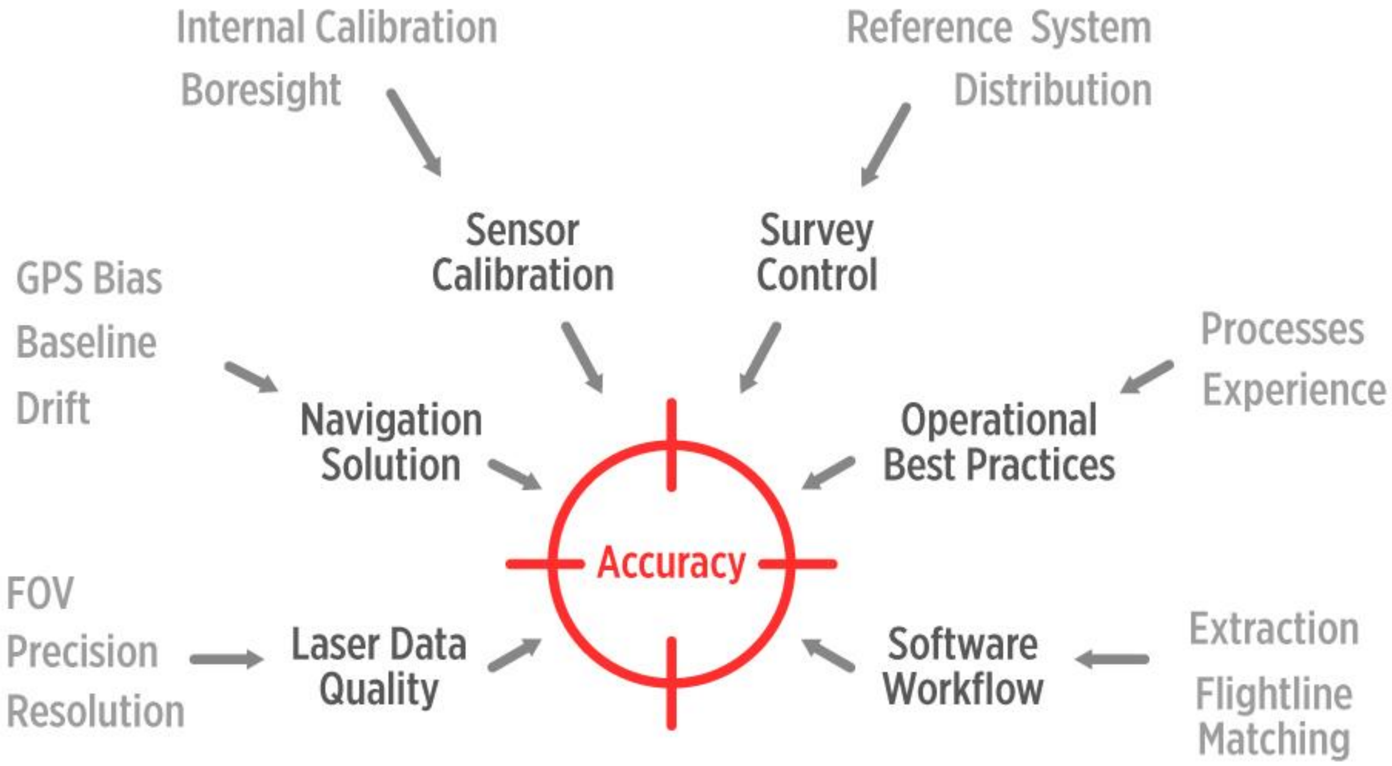


Active Sensing

- Active sensors provide their own source of energy to illuminate the objects they observe.
- An active sensor emits radiation in the direction of the target to be investigated.
- The sensor then detects and measures the radiation that is reflected or backscattered from the target.



Factors Affecting Accuracy

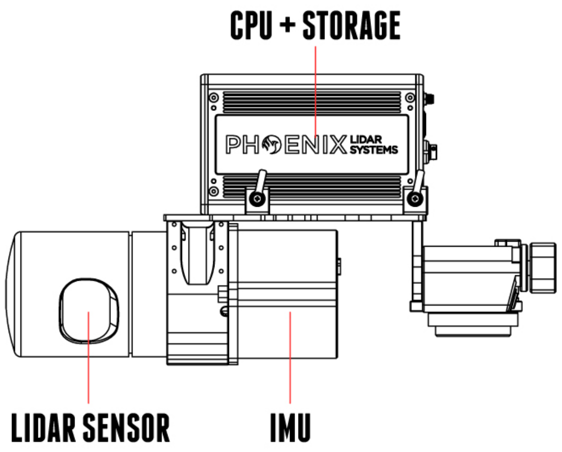


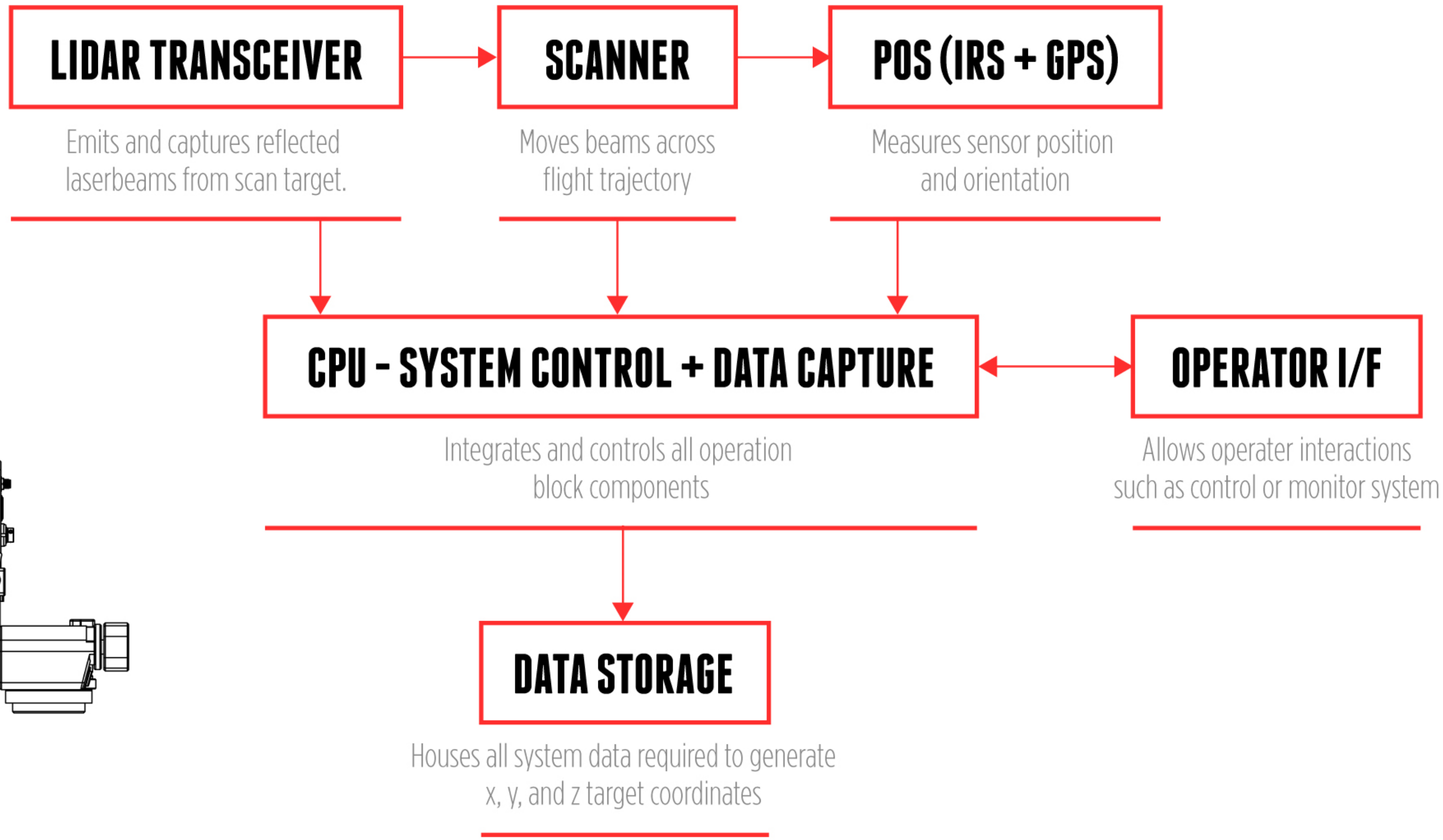
Rover Hardware

Pre-configured hardware during manufacturing facilitates setup procedure for the end user and is comprised of four major components:

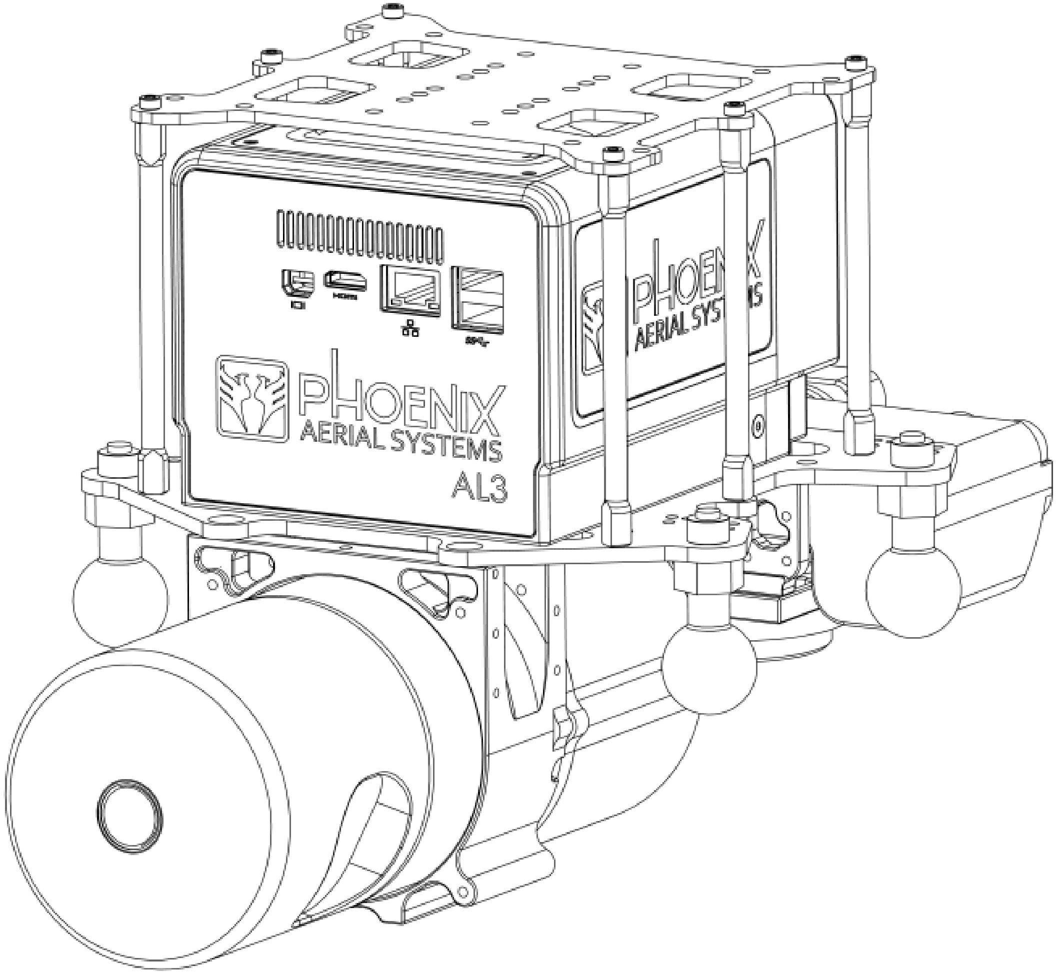
1. PC Module
2. IMU (Inertial Measurement Unit)/INS(Inertial Navigational Unit)
3. LiDAR Sensor
4. Camera (optional)

Rover Hardware





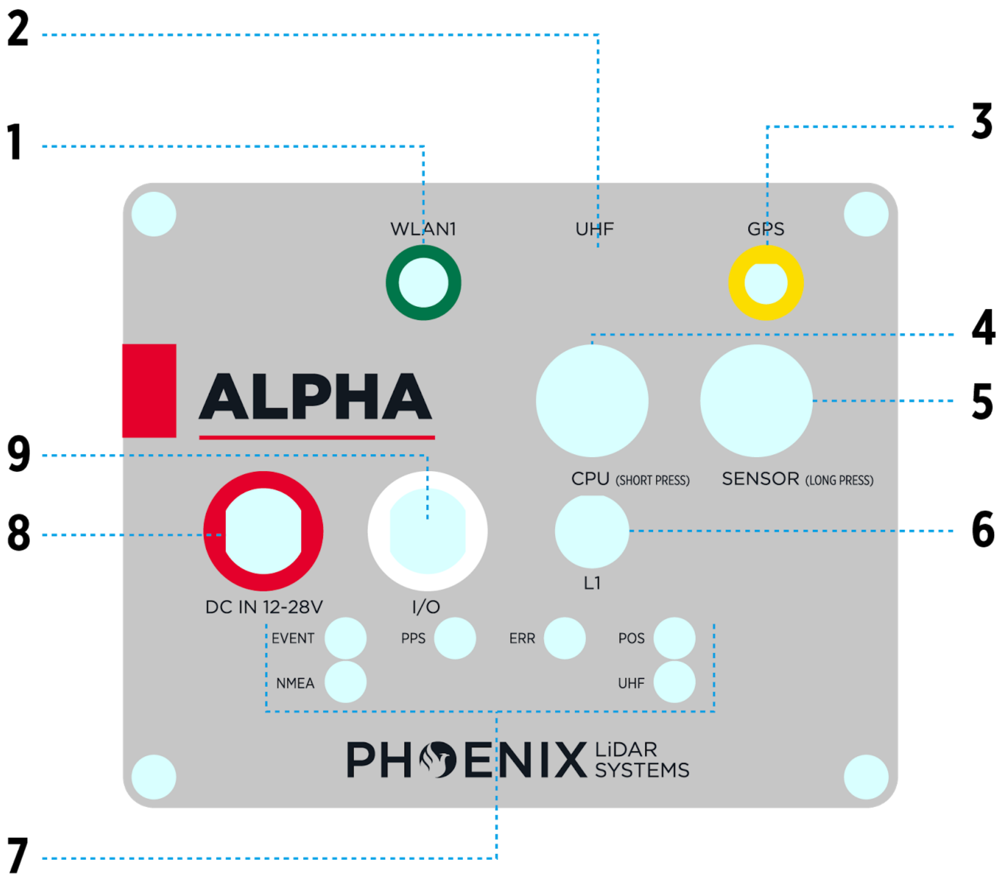
Rover Hardware



Rover Front Ports

The front panel of the PC Module includes:

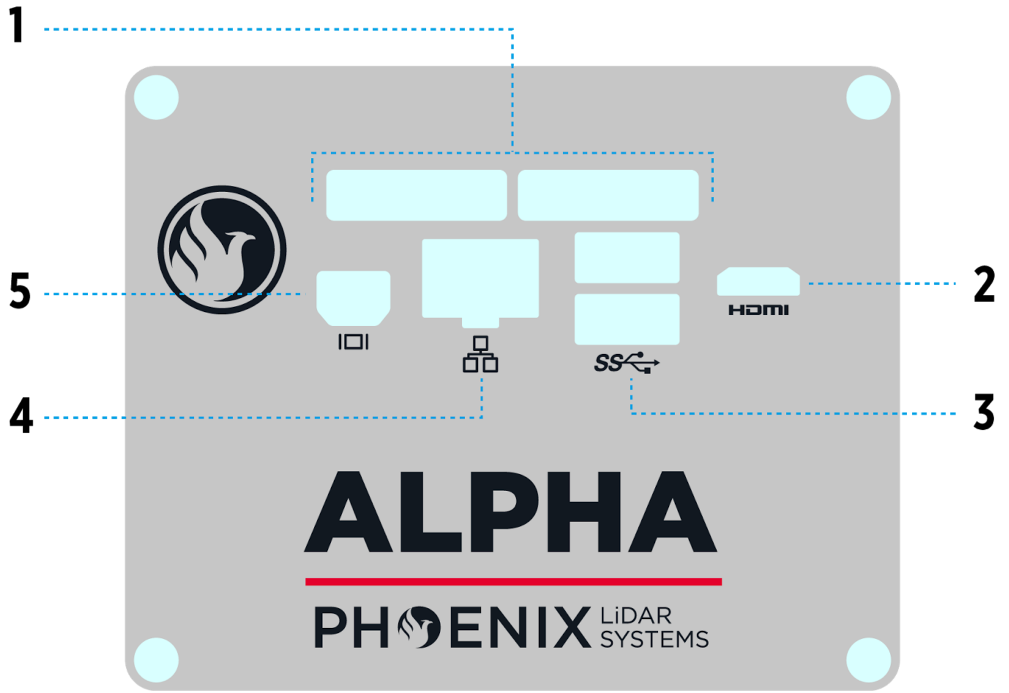
1. Wi-Fi antenna terminal/s
2. UHF antenna port (optional)
3. GPS antenna port/s
4. CPU power button
5. Sensor power button
6. LiDAR/IMU port
7. Status LED indicators
8. DC power input (12 V - 28 V)
9. External Input/Output data port



Rover Rear Ports

The back panel of the PC Module includes:

1. Exhaust vents
2. Mini HDMI port
3. USB 3.0 ports
4. LAN port
5. Mini DisplayPort



Log Files

- Multitude of data log files created during data collection session with timestamp records so that measurements taken at the same time can be correctly associated when post-processing.
- Files contain diagnostic messages as well as raw data captured from the system's sensors.
- Following table lists the type of log files created by the system.
  Any files not listed here are for special applications or diagnostic purposes.

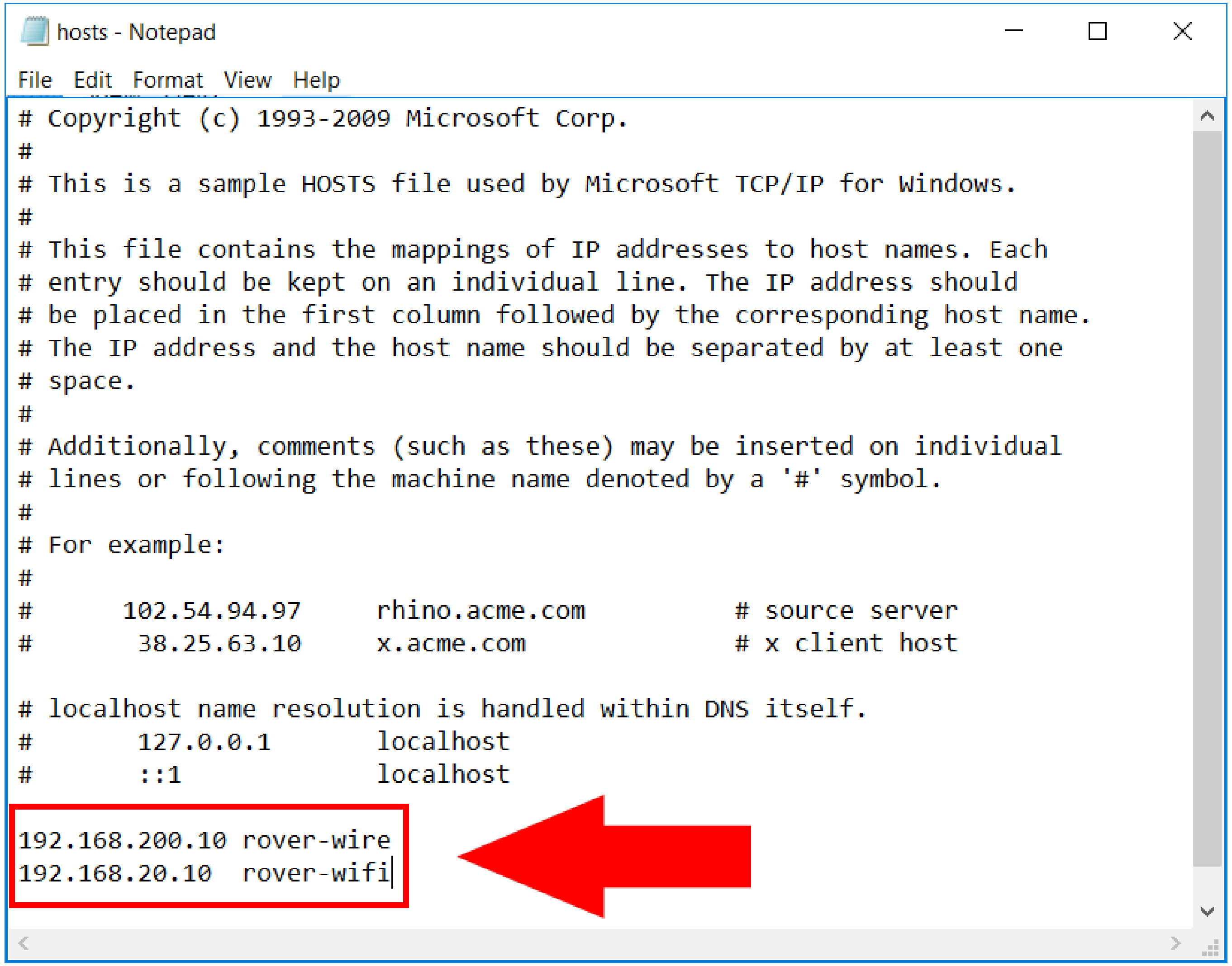
Log Files

<timestamp>.txt	Contains project descriptions that were entered in SpatialExplorer after scanning.
<timestamp>.nav	Contains data received from the navigation system, including the real-time solution as well as raw GNSS and IMU measurements.
<timestamp>.plp	Contains configuration and captured data from LiDAR sensor(s) as well as configuration and trigger-data about camera(s).
camX/	Folder containing photos taken with camX. Some cameras allow storing the images within the rover's log folder (e.g. Basler and Xenics cameras), others must be downloaded from the camera's internal storage (e.g. Sony Alpha 6000).

Rover Static IP Addresses

- Phoenix LiDAR Systems rovers are pre-configured with static IP addresses that can be reached via an ethernet (***192.168.200.10***) or a Wi-Fi connection (***192.168.20.10***).
- To avoid typing in the IP addresses, 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.

Rover Static IP Addresses



```
hosts - Notepad
File  Edit  Format  View  Help
# Copyright (c) 1993-2009 Microsoft Corp.
#
# This is a sample HOSTS file used by Microsoft TCP/IP for Windows.
#
# This file contains the mappings of IP addresses to host names. Each
# entry should be kept on an individual line. The IP address should
# be placed in the first column followed by the corresponding host name.
# The IP address and the host name should be separated by at least one
# space.
#
# Additionally, comments (such as these) may be inserted on individual
# lines or following the machine name denoted by a '#' symbol.
#
# For example:
#
#      102.54.94.97     rhino.acme.com          # source server
#       38.25.63.10     x.acme.com              # x client host

# localhost name resolution is handled within DNS itself.
#       127.0.0.1       localhost
#       ::1             localhost

192.168.200.10 rover-wire
192.168.20.10  rover-wifi
```

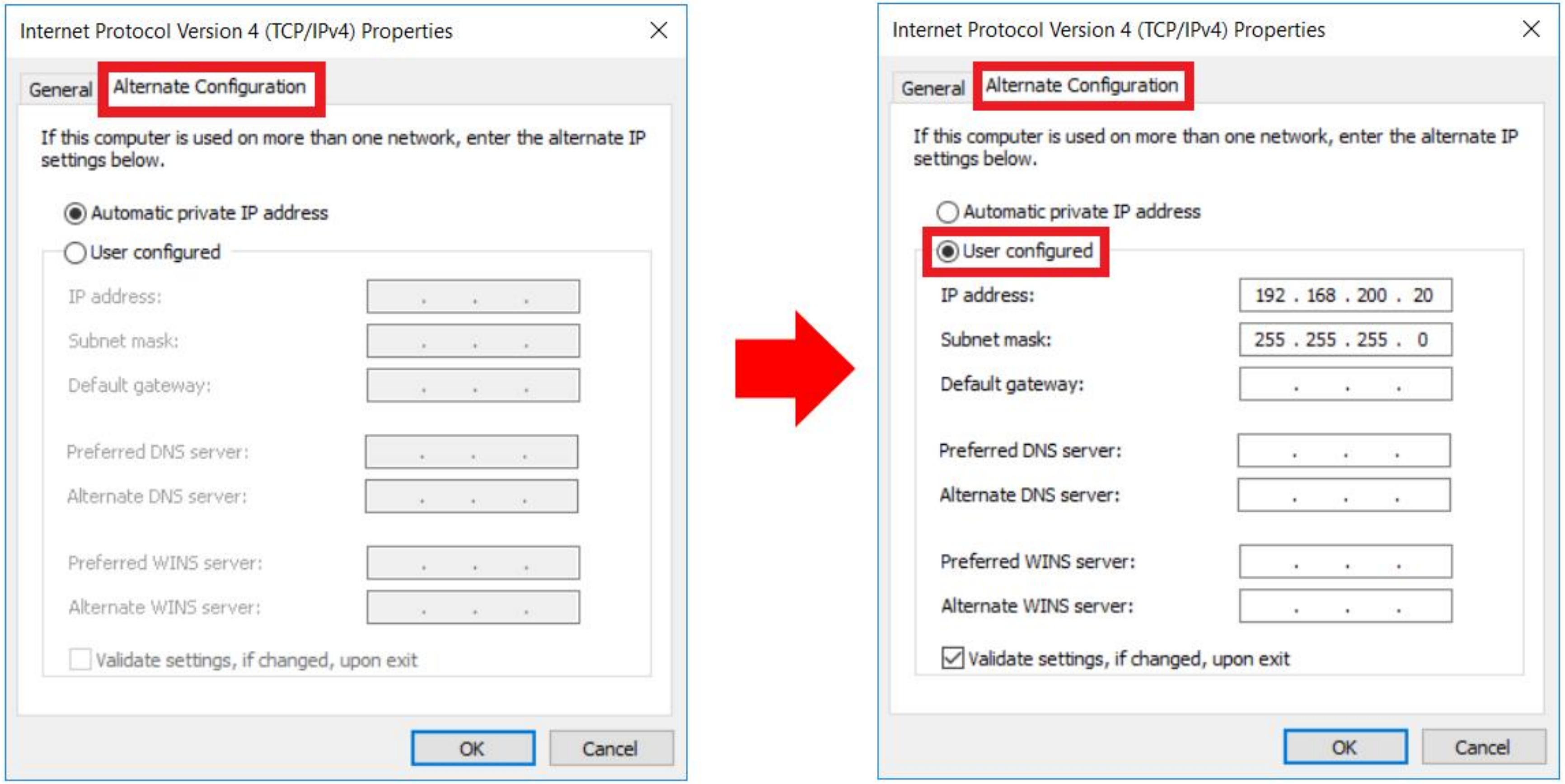
Wired Ethernet Network Card Setup

- A properly configured ethernet adapter can be used to establish a direct connection to the rover using an ethernet cable.
- Computers configured by Phoenix LiDAR Systems will default to 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 3 minutes of connection.

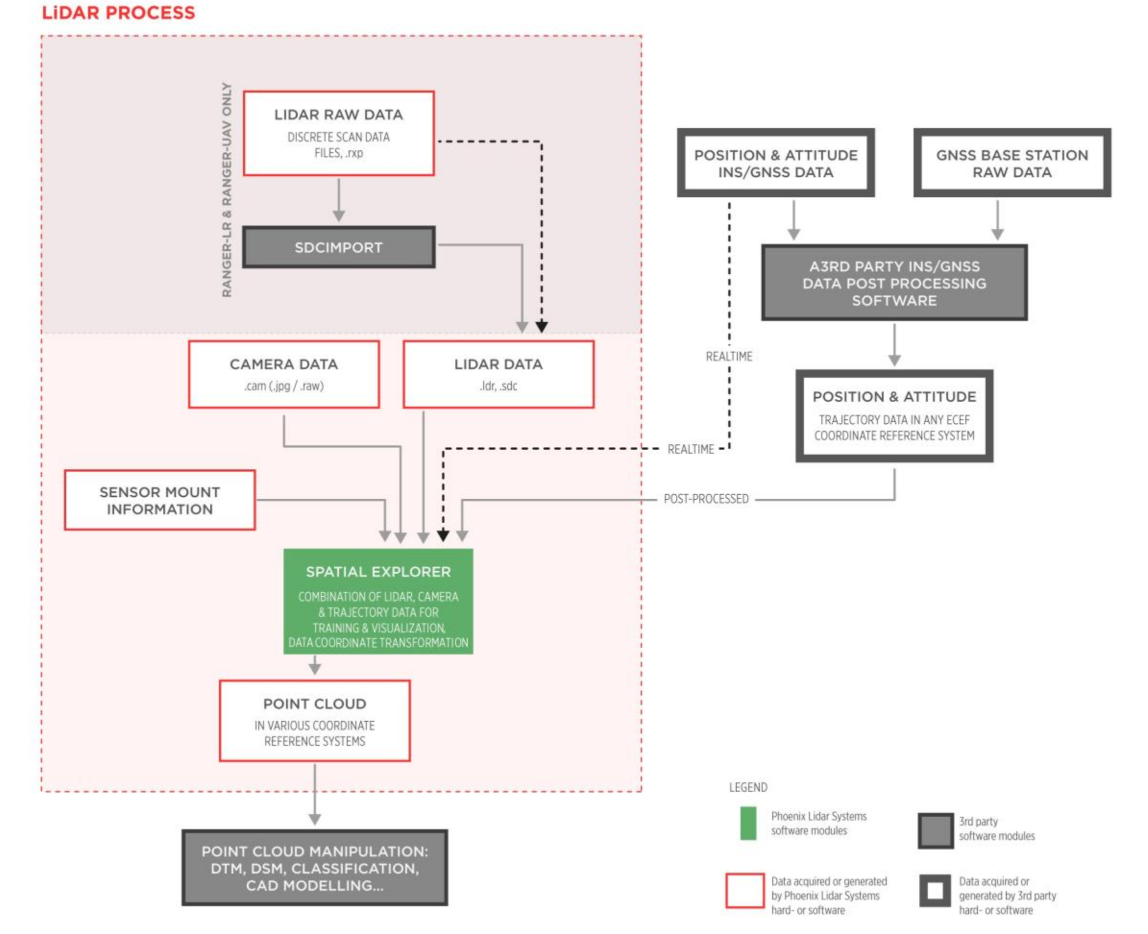
Wired Ethernet Network Card Setup

- 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.
- Alternatively a static IP can be set, however this is not recommended.

Wired Ethernet Network Card Setup



LiDAR Acquisition Workflow



PHOENIX LiDAR WORKFLOW

PHOENIX LiDAR Systems

Reference Station Setup

- The GNSS reference station logs differential corrections at intervals of 1 Hz (once per second).
- Configure the reference station's communication and protocol parameters to match the rover's corresponding parameters.
- Recommend mounting the reference station antenna with a clear view of the sky, away from buildings and powerlines.
- When applying power to the reference station, make sure to ONLY use a 4 cell Li-Po battery.

Reference Station Setup

1. Set up tripod and mount the reference station antenna onto the tripod.
2. Document the Antenna Reference Point (ARP) height above the marker.
3. Power the reference station and begin logging GPS+GLONASS raw observations at 1 Hz (automatically set).
4. Set up a portable computer (base station) and connect it to the reference station via Bluetooth or USB/Serial communication. If you are connecting via Bluetooth, the Bluetooth passkey is 1234.

Reference Station Setup

5. If you want to add differential corrections to your raw observations, launch SpatialLightHouse and configure the input to receive differential corrections from the reference station (USB/Serial or TCP/IP) and the output to transmit differential corrections to rover.
6. Start SpatialLightHouse session and wait until the session is configured. If transmitting RTK to rover, you must keep SpatialLightHouse open and running during the duration of the mission.

Field Scanning

- Before proceeding, if you are using a GNSS reference station:
  - Ensure it has been properly configured in SpatialLightHouse
  - Set to log raw observations of at least GPS+GLONASS at 1 Hz during the entire scanning procedure
  - Transmitting differential corrections (optional)
- We can now proceed with scanning mission and monitor the system to obtain an accurate scan.

Field Scanning

1. Place vehicle at takeoff site. If the system includes a Velodyne LiDAR sensor, take the cap off the LiDAR sensor.
2. Provide power to rover with either vehicle source or from a backup battery. We recommend using the vehicle as your main source and only temporarily using the battery power for “hot swapping” scenarios such as maintenance.
3. Power on rover.

Field Scanning

4. Launch SpatialExplorer and connect to rover to monitor the system.

- If connecting to the rover as a TCP client, make sure to use the correct Rover hostname:
    - Ethernet use ***rover-wire***.
    - Wi-Fi use ***rover-wifi***.
    - Over 3G/4G cellular connection, choose the Phoenix LiDAR Systems connection service and enter the corresponding license key.

Field Scanning

5. Leave rover powered on and idle at its takeoff site. If the included IMU is capable of static alignment, in order to obtain a reliable static alignment, the IMU must be completely static for a period of about 5-10 minutes.
6. LONG press the SENSOR button on the system to power on the LiDAR sensor. If the system includes a Velodyne LiDAR sensor, it must warm up for a period of 5-10 mins.

Field Scanning

7. Initiate mission and 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.
8. Conduct two to three sets of figure-eights to obtain an INS status of SolutionGood in SpatialExplorer. We recommend a figure eight pattern because it helps lower the covariances (Uncertainty Position and Uncertainty Attitude), which are estimated errors of position and attitude.
9. Once covariance values are low (approximately 0.0090 or less), activate the sensors (camera, LiDAR, etc.) within SpatialExplorer.

Field Scanning

10. Once you've finished scanning, deactivate the sensors from within SpatialExplorer.
11. Before ending mission, conduct another two to three sets of figure eights and 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.

❖ This will help mirror the alignment procedures if you intend to post-process the trajectory for increased accuracy.

Software Overview

SpatialSuite

- Phoenix LiDAR Systems provides a proprietary software suite for streamlined acquisition, geo-referencing, data fusion, and data export.
- Comprised of SpatialLightHouse and SpatialExplorer.
- Software suite can be downloaded from our website (requires authentication) and runs on any 64-bit version of Windows 8 and 10.

SpatialSuite

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.

How to Install SpatialSuite

- 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/AMD 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.4.0.

SpatialLightHouse

- Configure GPS reference station. SpatialLightHouse supports a wide variety of reference stations as well as various network topology configurations.
- Retrieve and process the data from GPS reference station.
- To post-process the rover's trajectory, data from the reference station is needed in the form of raw observations.
- Raw observations are all the measurements recorded by the reference station.

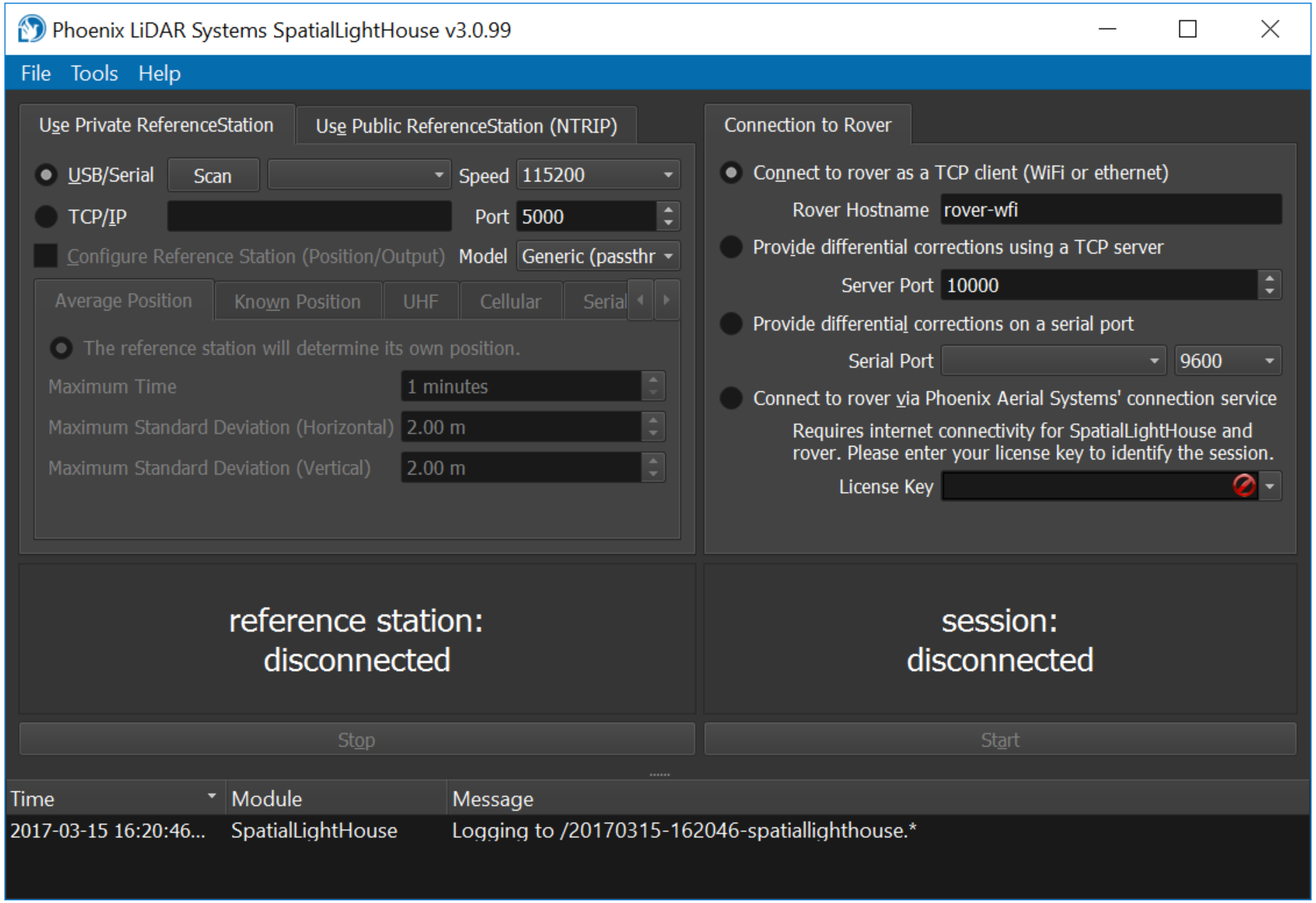
SpatialLightHouse

- Forward differential corrections (satellite errors derived from raw observations) obtained from the reference station to the rover.
- This method requires a fixed GNSS receiver (reference station).
- The rover can then apply these errors to its own measurements using a technique known as Real-Time Kinematic.
- RTK allows the rover to solve its own position in real-time to within centimeter-level accuracy.

SpatialLightHouse

SpatialLightHouse's features include:

- Optional tool to configure reference stations.
- Retrieves and processes data from reference station.
- Streams real-time corrections for trajectories and in-flight QA/QC.
- Logs raw observations for post-processing.
- Supports NTRIP.
- Leica and CHC reference stations can be setup to send corrections directly to rover via UHF/3G/4G.


Phoenix LiDAR Systems SpatialLightHouse v3.0.99
File Tools Help
Use Private ReferenceStation
Use Public ReferenceStation (NTRIP)
USB/Serial
Scan
Speed 115200
TCP/IP
Port 5000
Configure Reference Station (Position/Output)
Model Generic (passthr
Average Position
Known Position
UHF
Cellular
Serial
The reference station will determine its own position.
Maximum Time
1 minutes
Maximum Standard Deviation (Horizontal)
2.00 m
Maximum Standard Deviation (Vertical)
2.00 m
Connection to Rover
Connect to rover as a TCP client (WiFi or ethernet)
Rover Hostname rover-wfi
Provide differential corrections using a TCP server
Server Port 10000
Provide differential corrections on a serial port
Serial Port
9600
Connect to rover via Phoenix Aerial Systems' connection service
Requires internet connectivity for SpatialLightHouse and rover. Please enter your license key to identify the session.
License Key
reference station: disconnected
session: disconnected
Stop
Start
Time
Module
Message
2017-03-15 16:20:46...
SpatialLightHouse
Logging to /20170315-162046-spatiallighthouse.*

SpatialExplorer

- SpatialExplorer can monitor and control LiDAR mapping systems offered by Phoenix LiDAR Systems in real-time (see what you're scanning while you're scanning it) and replay and visualize LiDAR mapping missions in post.
- Due to the heavy graphics intensity required to display LiDAR data, SpatialExplorer (version 3.5 and above) requires an OpenGL 4.3 driver installed. Both NVIDIA and AMD Radeon graphics cards are supported. Older versions of SpatialExplorer (version 3.0.9 and below) require at minimum an NVIDIA GeForce GTX 850M with 2GB VRAM and a recent OpenGL driver installed.

SpatialExplorer

- Enables in-field quality control and analysis and ensures obtaining a quality solution throughout the acquisition process.
- Permits user to calibrate camera settings without needing to rely on sending in units for "vendor-only-calibration" or adjustments.
- An exceptional tool for training with how-to-fly visualizations.
- Furthermore, it allows for the creation of high quality marketing imagery of acquired scans.

SpatialExplorer

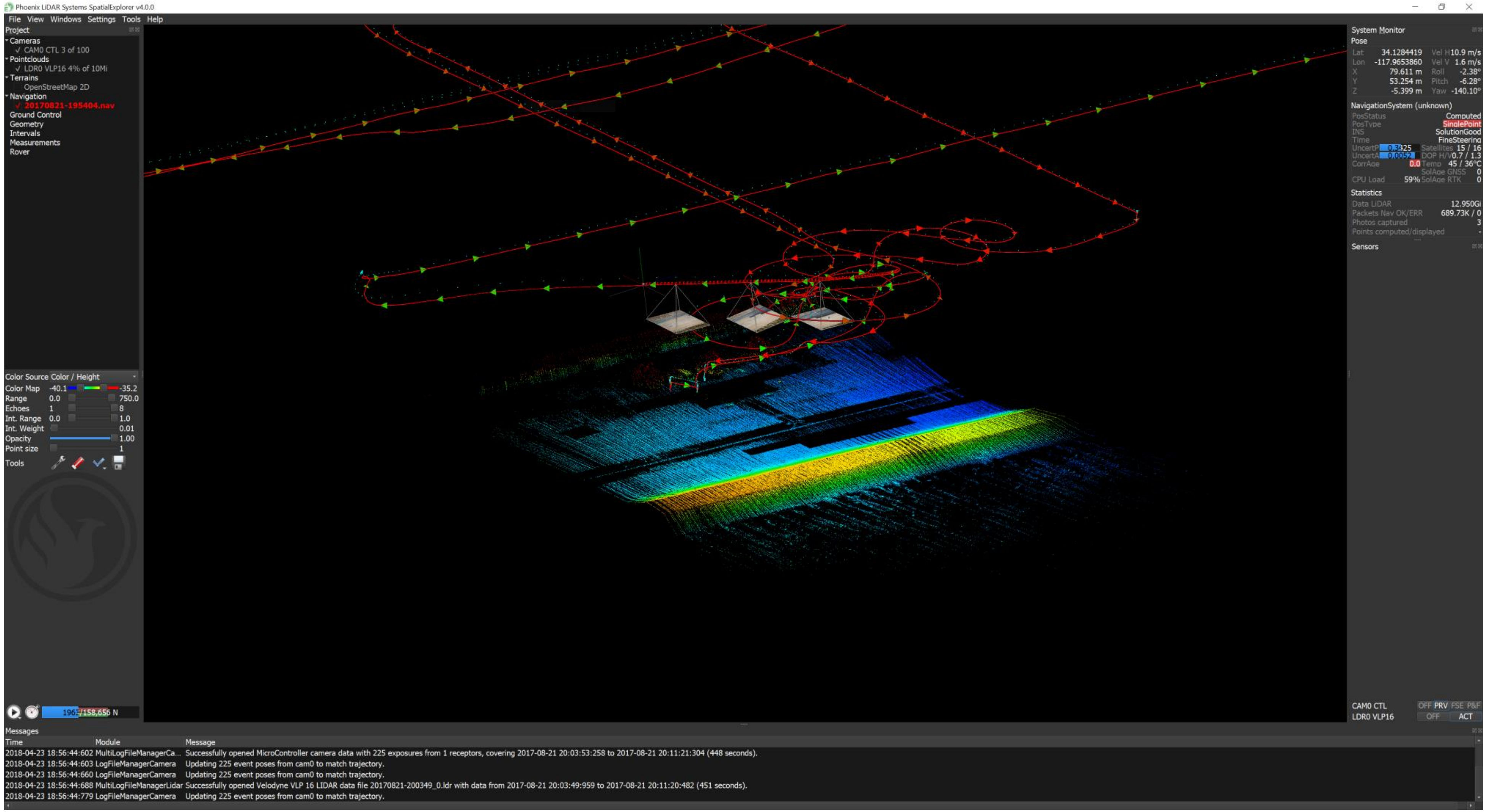
Highlights include:

- Real-time, 3D, georeferenced point cloud visualization.
- Real-time RGB colorization.
- Real-time measurements and profile analysis.
- Monitor a variety of LiDAR system parameters.
- Real-time photo preview (specific camera upgrades only)
- Included flight-plan module.
- Connect to a 3G/4G enabled rover from anywhere and with as many SpatialExplorer sessions.

SpatialExplorer

SpatialExplorer post-processing features include:

- Fusing raw data from rover into LAS or LAZ point clouds.
- Creating accurate, georeferenced, colorized point clouds from real-time or post-processed trajectories.
- Intuitive manual extraction of flight lines, or fully automated processing.
- Exporting point clouds to more than 4000 coordinate systems.



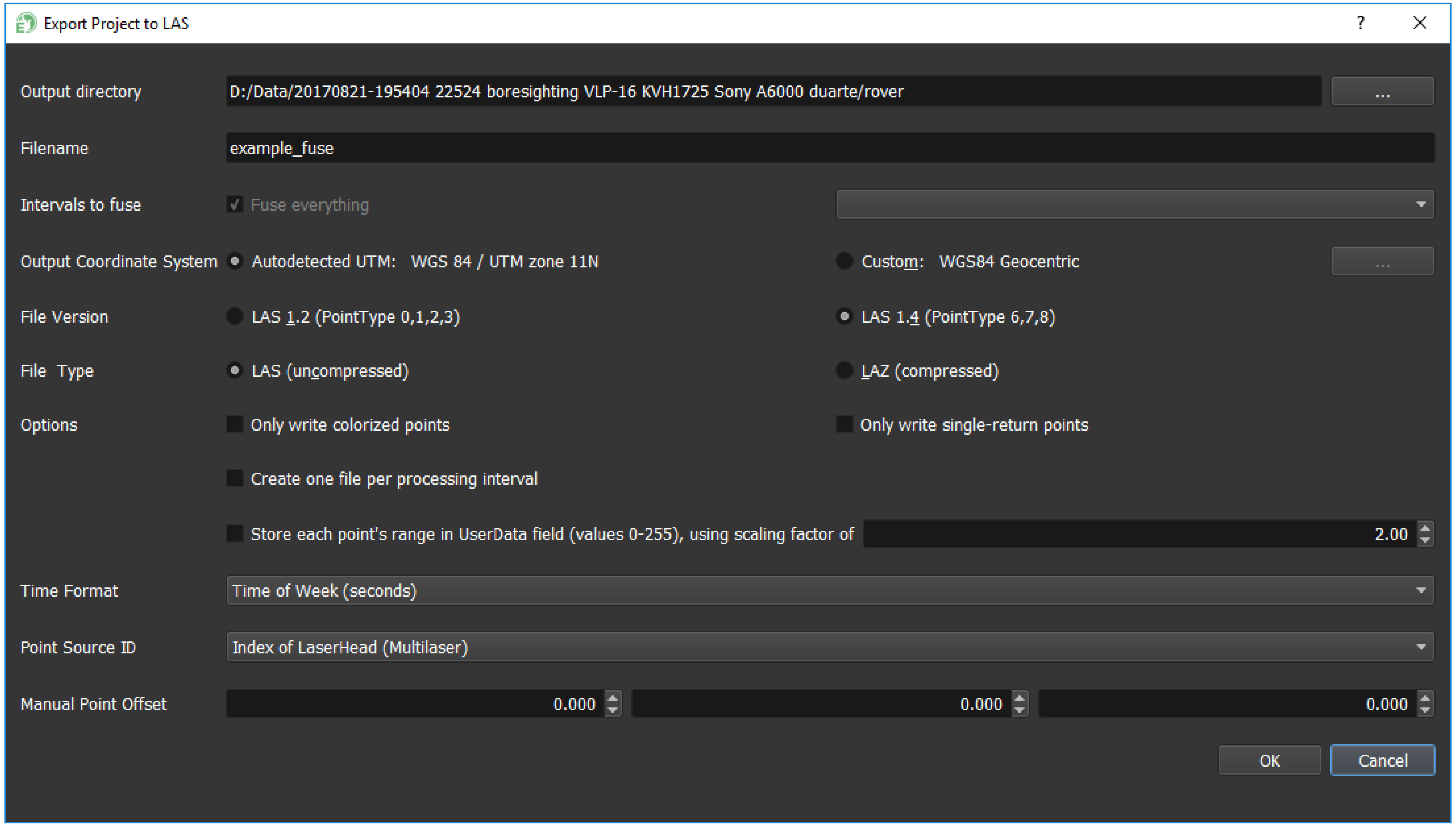
PHOENIX LiDAR SYSTEMS

SpatialExplorer

- Transform LiDAR/image sensor data into a georeferenced point cloud.
- Can also produce image sensor processing files by visualizing and determining the quality of the navigation system trajectory data.
- Make post-processing adjustments to a subset of sensor settings and features within and limit what data is considered in the final export and fusing process.
- Determine the final export settings for your data.

SpatialExplorer

- Georeference data acquired by our LiDAR mapping systems into common mapping formats such as LAS/LAZ.
- Cuts down the wait time on extensive photogrammetry applications by creating colorized point clouds in about twice the time of the acquisition.
- Offers support for GNSS and INS navigation systems.
- Furthermore, SpatialExplorer supports multiple remote sensing equipment configurations.


Export Project to LAS
Output directory
D:/Data/20170821-195404 22524 boresighting VLP-16 KVH1725 Sony A6000 duarte/rover
...
Filename
example_fuse
Intervals to fuse
Fuse everything
Output Coordinate System
Autodetected UTM: WGS 84 / UTM zone 11N
Custom: WGS84 Geocentric
File Version
LAS 1.2 (PointType 0,1,2,3)
LAS 1.4 (PointType 6,7,8)
File Type
LAS (uncompressed)
LAZ (compressed)
Options
Only write colorized points
Only write single-return points
Create one file per processing interval
Store each point's range in UserData field (values 0-255), using scaling factor of
2.00
Time Format
Time of Week (seconds)
Point Source ID
Index of LaserHead (Multilaser)
Manual Point Offset
0.000
0.000
0.000
OK
Cancel