PHOENIX LiDAR SYSTEMS

LIDAR Selection Guide

Considerations, Comparisons, Current Scanners

Overview

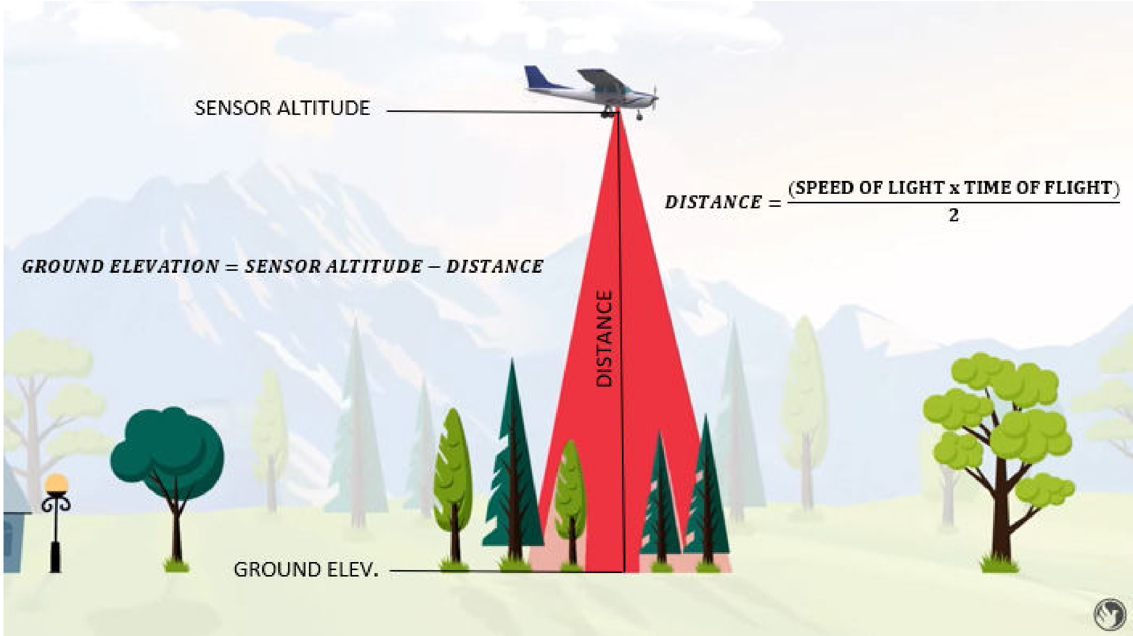

WATT'S ENGINEERING SKYPRISME DRONE WITH THE PIONEER LIDAR SYSTEM

What is LIDAR?

- LIDAR is an active remote sensing system.
  - A LIDAR instrument fires rapid pulses of laser light at a surface.
  - Repeating the pulses in quick succession, the instrument then builds up a complex map.
  - As the sensor moves location, height and orientation, a GPS Navigation Sensor System/ Inertial Measurement Unit (GNSS / IMU) instrument must be included to determine its position and orientation.
  - These lasers are lower powered and are classed as ‘eye-safe’ allowing them to be used with little safety precautions.

Light Detection and Ranging (LIDAR)

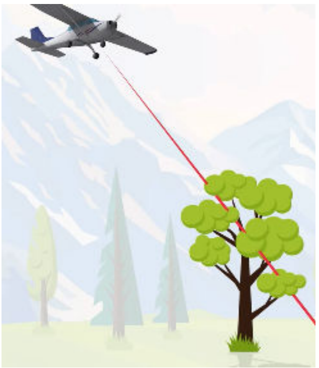
- The principle behind LiDAR is really quite simple. Shine a small light at a surface and measure the time it takes to return to its source.

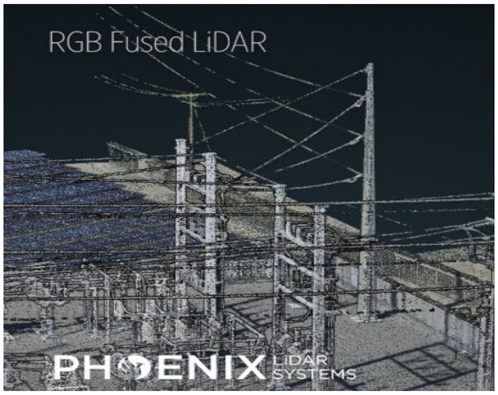


Active vs Passive Remote Sensing

LiDAR (Active)

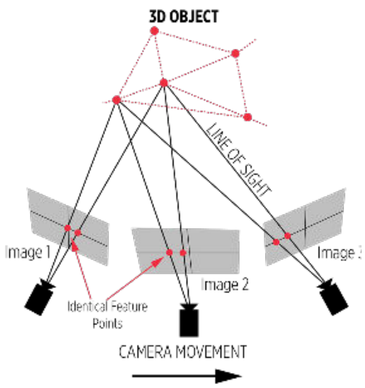
- Multiple Returns to allow one beam of light several opportunities to penitrate vegitation canopies to measure the ground below.
- Since LIDAR uses its own light source you can use it day or night.
- Because the drone position is known, using a laser creates a highly accurate vertical measurement.

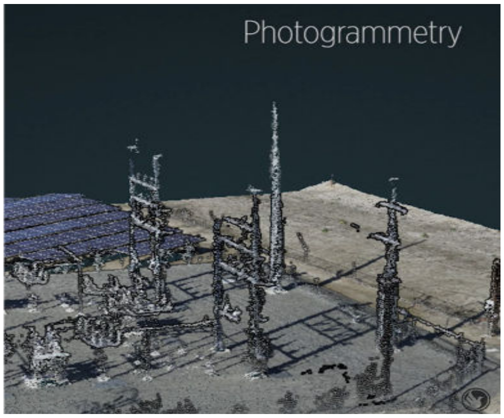




Photogrammetry (Passive)

- Because photogrammetry uses light from secondary source, objects need to be stationary.
- Due to the fact this method uses cameras, the time of day for capture it limited.
- Needs high contrast areas and cannot detect small objects like power lines.
- Produces easy to interpret color models
- Since it uses ground triangulation, photogrammetry is better for horizontal measurements like curb and gutter.





Value proposition for both

Combining LIDAR and photogrammetry data can provide a more comprehensive understanding of the landscape. It can provide several benefits and creates a more complete picture to the average viewer of the data:

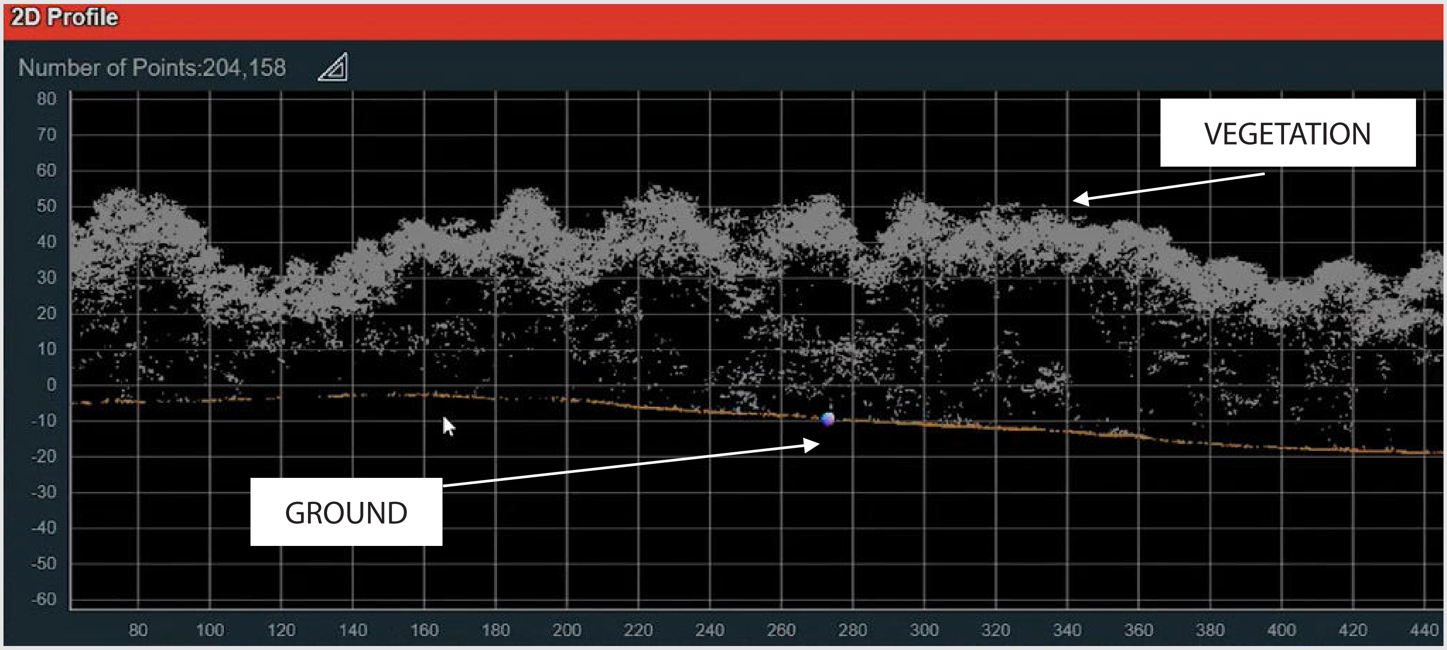
- Improved accuracy and precision: Highly accurate elevation measure-ments (LIDAR) + detailed color and texture of the terrain (photogrammetry) = highly accurate and detailed 3D models of the landscape

- Increased flexibility: Detailed DEM / DTM + simultaneous orthomosaics = provides different types of information and analysis

- Enhanced feature extraction: Extract more detailed information about the features of the landscape, such as buildings, roads, and vegetation. Photogrammetry provides detailed information about the color and texture of objects, while LIDAR can provide information about their shape and location.

- Increased coverage: LIDAR can be used to quickly survey large areas, while photogrammetry can be used to provide detailed information about specific areas of interest.

Why Lidar?



Drone lidar is becoming an increasingly popular technology in various industries, such as forestry, construction, and surveying. One of the primary advantages of drone lidar is its ability to capture small structures like vegetation and tower lattice without the need for 3rd party light sources. This is possible due to the high-resolution laser scanner that emits pulses of light that bounce back from objects, creating a detailed 3D map of the terrain. With a high point density high precision system, lidar can detect small objects like tree branches and leaves, providing a more accurate representation of the vegetation cover in the area. This level of detail is not possible with traditional surveying methods like photogrammetry, which relies on contrast to differentiate between objects.

Another significant advantage of drone lidar is its ability to penetrate through vegetation, known as vegetation penetration. The laser scanner emits pulses of light that can pass through the foliage and bounce back from the ground below, allowing for accurate measurements of the terrain. This is particularly useful in industries like forestry, where traditional methods of terrain mapping struggle to provide accurate ground measurements due to the dense vegetation cover. With the right sensor, drone lidar can provide accurate elevation data even under dense forest canopies, allowing for better forest management and monitoring of tree growth and health. Overall, drone lidar offers a high level of accuracy and detail, making it an invaluable tool for various industries that require detailed terrain mapping and analysis.

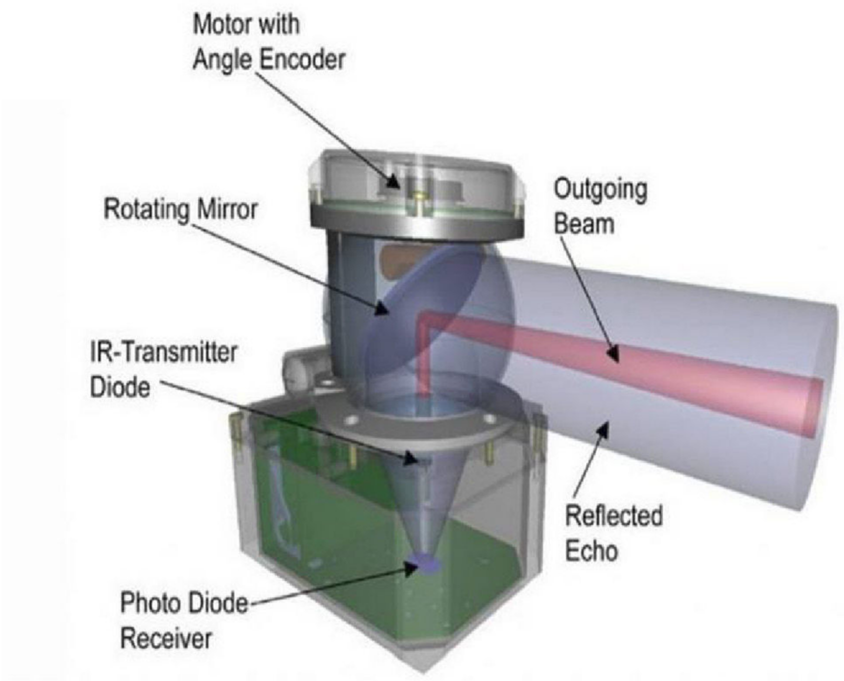
Reasons to UAV LiDAR

- Easy mobilization
- Low operation costs
- Through mass production of sensors & GNSS available to manufacture even in small companies
- Data quality compared to 'professional' systems not as high but sufficient to many targets
- Lot of small projects and new applications like supplementary mapping, project monitoring etc.
- Compared to photogrammetric point clouds can see ground also on covered areas
- Special targets like power lines
- Lot of potential new users

LIDAR Scanner Components

Most LiDAR scanners have these main components:

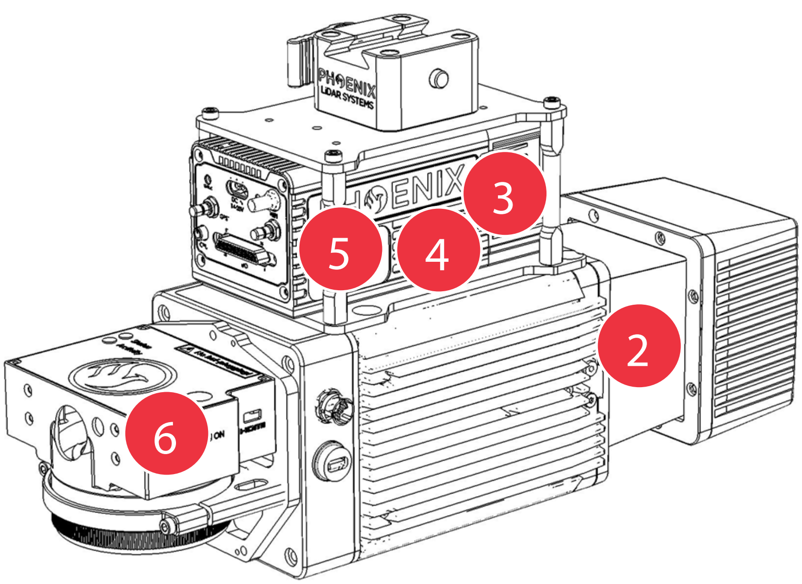
1. Lasers
2. Scanners and optics
3. Photodetector and receiver electronics



Most integrated LiDAR systems also have:

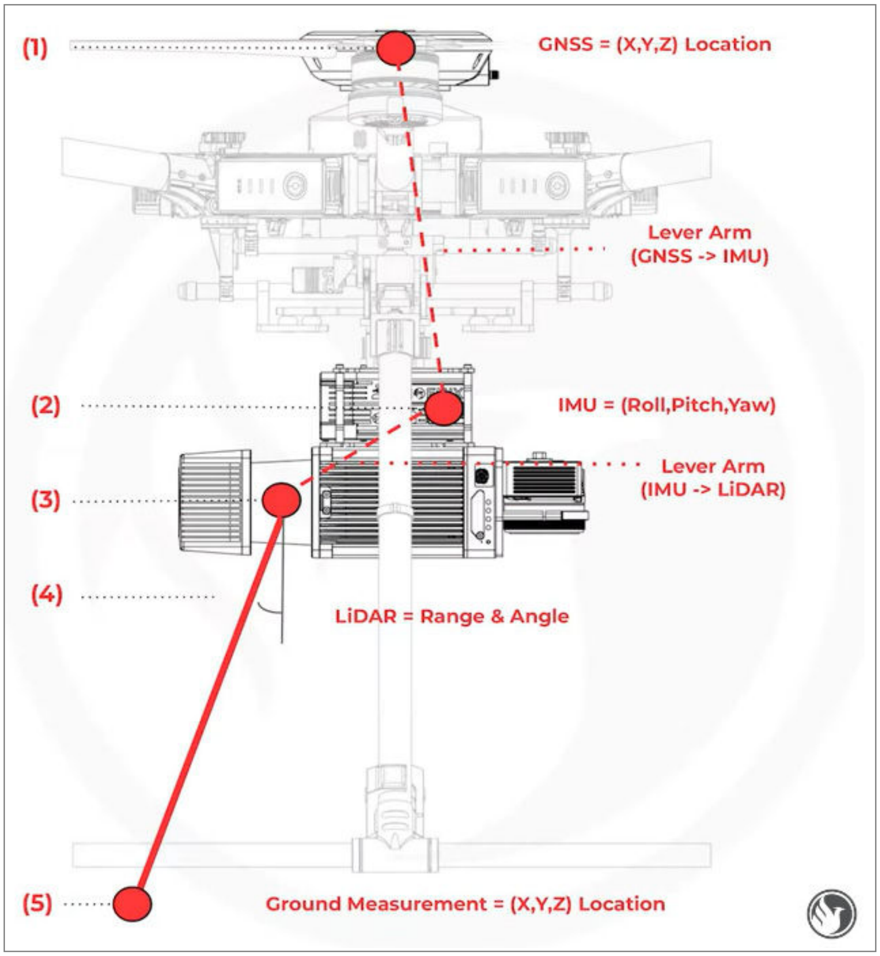
1. Power supply
2. Recording device
3. GPS / IMU

UAS LIDAR System Components



	UTILITY	COMPONENT
1	Positioning	GNSS Antenna / Receiver
2	Ranging	LIDAR (Light Detection and Ranging)
3	Orientation	Inertial Measurement Unit (IMU)
4	Data Storage	Hard Drive / SD Card
5	Computation	Central Processing Unit (CPU)
6	Imagery	Camera (optional)

UAS LIDAR System Components



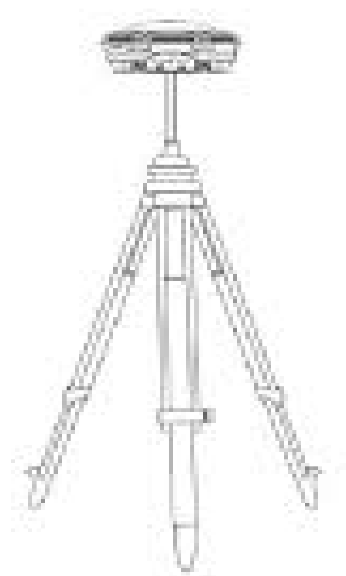
LEVER ARMS

One Consideration is Leverarms. As shown to the left by the dotted red lines, your LIDAR system has to know the exact position of the GNSS antenna in reference to the IMU. The same is true between the lidar and IMU. If these measuremetns are incorrect, your data will have positional errors.

Some platform/sensor combinations you will need to mount and then measure. Other systems have fixed mount points and these distances come preloaded in the system.

Basestation

A ground basestation is an important part of your LIDAR solution. A GNSS ground station allow the LIDAR's GNSS to correct for GPS constellation errors. Generally speaking Real-time Kinematic (RTK) correction achieves 3 to 4 cm accuracy. Post Processing Kinematic (PPK) correction, done after LIDAR capture, acheves 2 cm of accuracy.

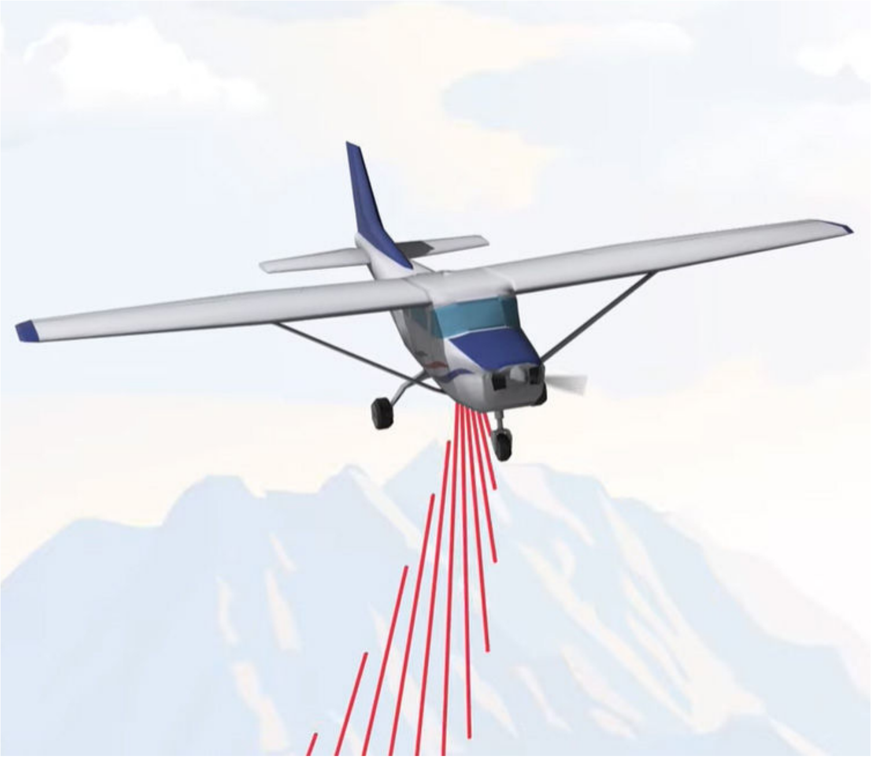


LIDAR Technical Specifications

- Laser Pulse Repetition Rate (PRR)
- Laser Beam Divergence
- Laser Beam Field of View (HFOV / VFOV)
- Echo / return
- Intensity
- Laser wavelength
- Accuracy (relative / absolute)
- Precision

Harris Aerial H6 Gas Hybrid with Ranger LR

LIDAR Technical Specifications



Laser Pulse Repetition Rate PRR

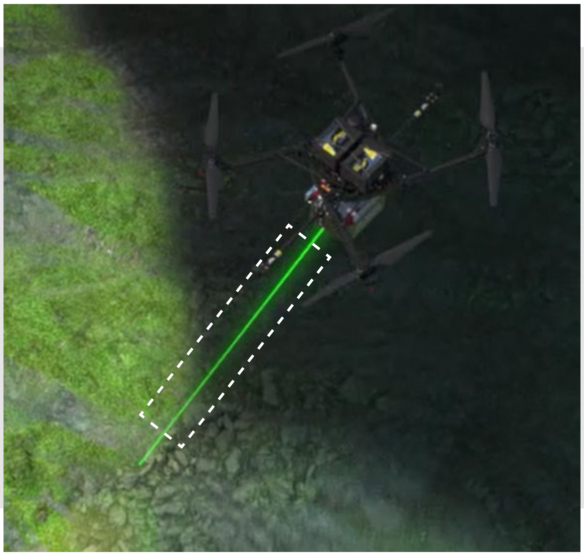
The laser Pulse Repetition Rate (PRR), or Pulse Repetition Frequency (PRF) is the number of laser pulses emitted by a LIDAR system per second.

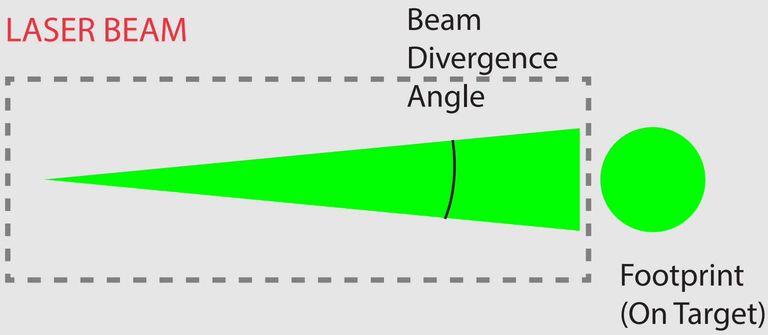
It is an important consideration when selecting a LIDAR system because it directly affects the point density, or the number of points captured per unit area, of the LIDAR data.

A higher PRR results in a higher point density, which can provide more detailed and accurate information about the environment being scanned.

This increased point density can be especially useful for enhanced feature extraction, such as identifying small objects or detecting subtle changes in the environment.

LIDAR Technical Specifications





Laser Beam Divergence

Laser beam divergence refers to the angular spread of the laser beam as it travels away from the LIDAR sensor.

It is typically measured in milli radians and is determined by the properties of the laser and the specific design of the LIDAR sensor.

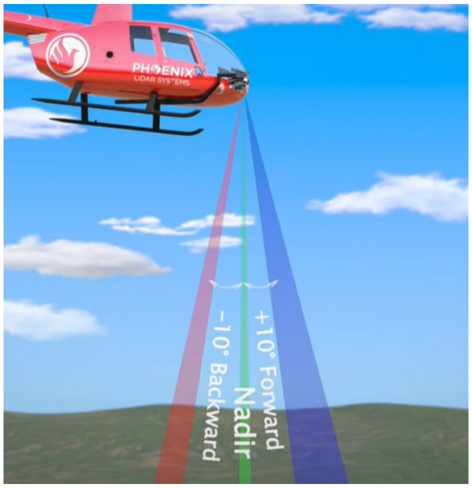
Laser beam divergence is an important consideration when selecting a lidar system because it affects the sensor's precision, accuracy, and ranging performance.

A narrow beam divergence allows the LIDAR to measure distances with a high degree of precision, while a wide beam divergence can result in a lower ranging performance and lower accuracy measurements.

This is because as the beam divergence increases, the laser energy is distributed over a larger area (footprint), which results in a lower signal-to-noise ratio, and thus a lower ranging performance.

LIDAR Technical Specifications

HFOV



VFOV

LiDAR Sensor Field of View

The LIDAR sensor's horizontal field of view (HFOV) and vertical field of view (VFOV) refer to the angular range that the sensor can detect in the horizontal and vertical planes, respectively.

The HFOV and VFOV are typically measured in degrees and are important considerations when selecting a LIDAR system because they determine the sensor's coverage area and the ability to detect objects at a wider range of angles.

A wide HFOV will provide a larger coverage area, allowing the sensor to detect objects over a wider range.

A wide VFOV allows the sensor to detect objects at a wider range of angles which is beneficial for mapping complex vertical structures.

An example of a sensor with a wide VFOV is the RANGER-Ultra (pictured right) with its NFB (Nadir Forward Backward) scan capability, which minimizes laser shadowing and provides enhanced geometry on complex vertical structures. NFB is achieved by using a 3 faceted mirror, which allows creating a virtual multi-laser , allowing the sensor to scan at nadir, and also +/- 10° off nadir, as opposed to a traditional multilaser sensor configured with multiple lasers, or channels, positioned at different angles relative to each other.

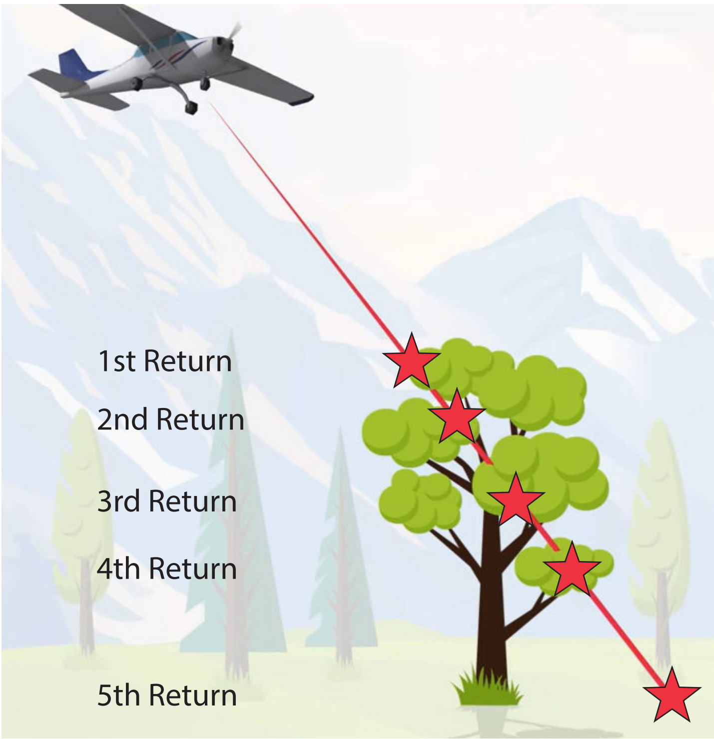
LIDAR Technical Specifications

LIDAR Return / Echo

A LIDAR return refers to the signal that is reflected back to the lidar sensor from an object or surface in the environment.

When a laser beam is emitted from the sensor, it reflects off objects in the environment and some of that light is then reflected back to the sensor.

The sensor then measures the time it takes for the light to travel to the object and back, as well as the strength of the signal, to determine the distance and location of the object in 3D space.



The number of returns per pulse refers to the number of times that the lidar sensor can detect a measurement in a single pulse of the laser.

The more returns per pulse, the more data that can be collected in a single measurement.

A high number of returns per pulse can produce a dense point cloud with a high level of detail, which can be useful for applications such as mapping and surveying.

A low number of returns per pulse can produce a sparse point cloud with less detail, which may not be suitable for these applications.

Considering the maximum number of returns per pulse is important when dealing with complex and cluttered environments, where multiple objects are present in the same line of sight.

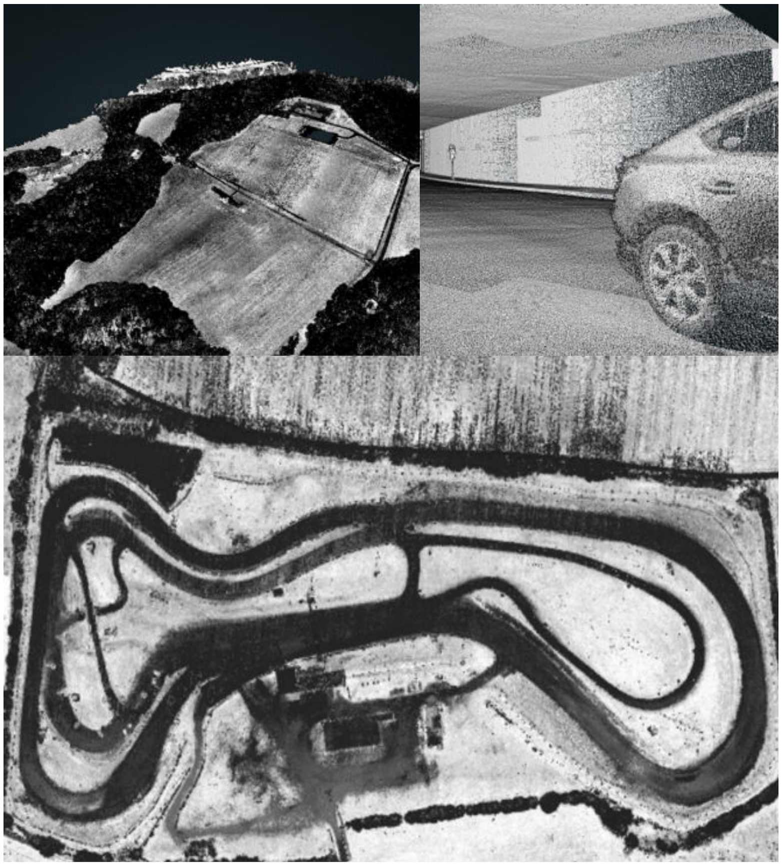
In those cases, a LIDAR sensor with a high number of returns per pulse would be better at capturing more information and avoiding missing data.

LIDAR Technical Specifications

Return Intensity

LIDAR return intensity refers to the strength of the signal that is reflected back to the lidar sensor from an object or surface in the environment. It is measured in arbitrary units, such as digital numbers (DN) or decibels (dB).

Intensity values of the LIDAR returns can be used to enable false colorization of the point cloud, where different intensities are assigned different colors to better visualize the point cloud data. This can help to distinguish between objects and surfaces of different reflectivity, making it easier to identify and classify different features in the environment.



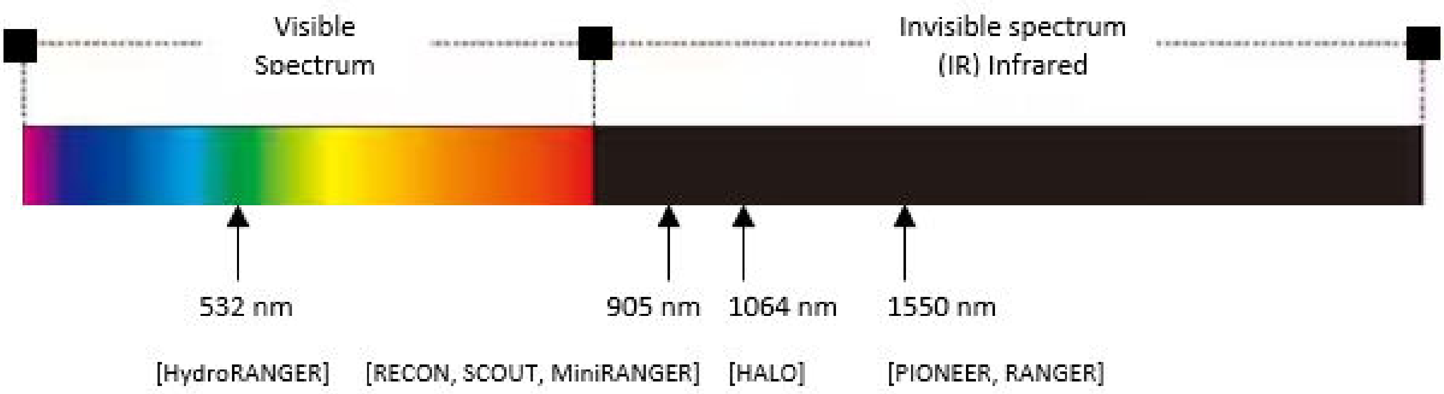
Return intensity is an important factor when selecting a LIDAR system because it directly affects the quality and accuracy of the lidar data, as well as the ability to detect or classify objects, such as weakly reflective surfaces.

It's important to note that target reflectance values vary for each laser wavelength. For example, a deciduous tree has a 60% target reflectance with a 905nm laser, and a 30% reflectance with a 1550nm laser.

When planning the use of a LIDAR system, the user should consider the type of environment that the LIDAR will be operating in along with the minimum detectable reflection required for the application.

LIDAR Technical Specifications

Laser Wavelength



Laser wavelength refers to the distance between consecutive peaks (or troughs) of a laser beam's electromagnetic waves.

The choice of wavelength for a LIDAR system will depend on the specific requirements of the application, such as range, accuracy, and the atmospheric conditions in which the LIDAR system will be used.

532 nm: This green wavelength is used primarily for bathymetric LIDAR applications, which involve measuring the depth of water bodies. These systems typically have a short range, but they are able to penetrate the water surface and provide accurate depth measurements. The green wavelength is also more visible, making it easier to detect, but it is more strongly absorbed by atmospheric particles, which reduces its range and effectiveness in certain conditions.

905 nm: This near-infrared wavelength is commonly used for drone LIDAR systems. 905 systems perform better in conditions of high humidity, such as wet and foggy sites. This makes a 905 laser a good option for lower vegetation and less mountainous terrain.

1064 nm: This longer-wavelength near-infrared light is even less absorbed by atmospheric particles, making it ideal for long-range LIDAR systems such as those used in high altitude aerial mapping and surveying applications.

1550 nm: This wavelength is typically used for LIDAR systems that can adapt between drones and crewed aircraft as these systems are high powered and produce lower data noise. It is a common wavelength for high-resolution, and high accuracy mapping and surveying applications with ranges typically lower than the 1064 systems.

LIDAR Technical Specifications

Absolute Accuracy

Absolute accuracy is an evaluation of how well the measurements (LiDAR Points) of a dataset align with the true or accepted real values.

The true values for a project area / datum are generally established by a source of known higher accuracy, such as a professional land survey.

LiDAR is considered a digital elevation data source, and is commonly evaluated against truth points in the vertical direction only.

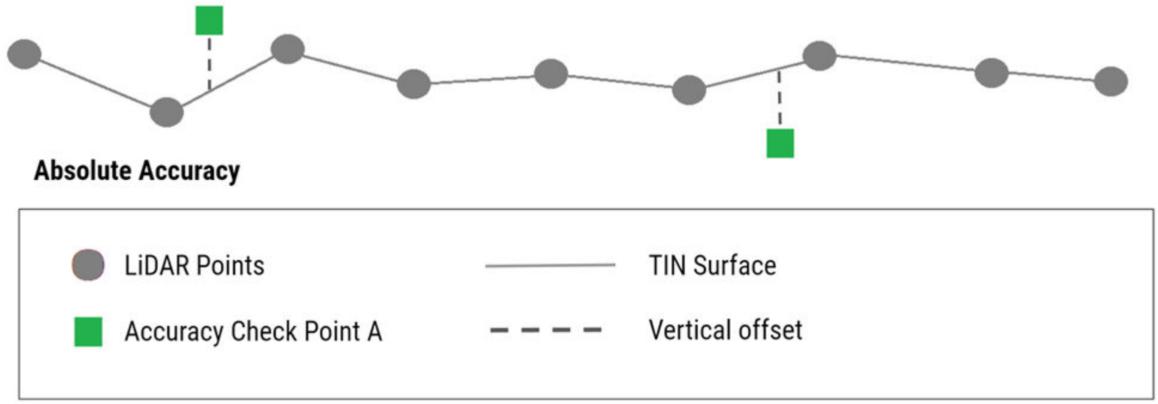
Absolute Accuracy Equation:

$$RMSE_z = \sqrt{\frac{\sum_{I=1}^{n}({}^{z}data\ I - {}^{z}check\ I)^2}{n}}$$

^{z}check I = vertical coordinate of the Ith surveyed accuracy check point in the independent source of higher accuracy

^{z}data I = vertical coordinate of the corresponding Ith check point in the TIN Surface generated from lidar dataset
Note: ^{z}data I - ^{z}check I = Vertical offset

n = number of check points tested
I = integer ranging from 1 to n



LIDAR Technical Specifications

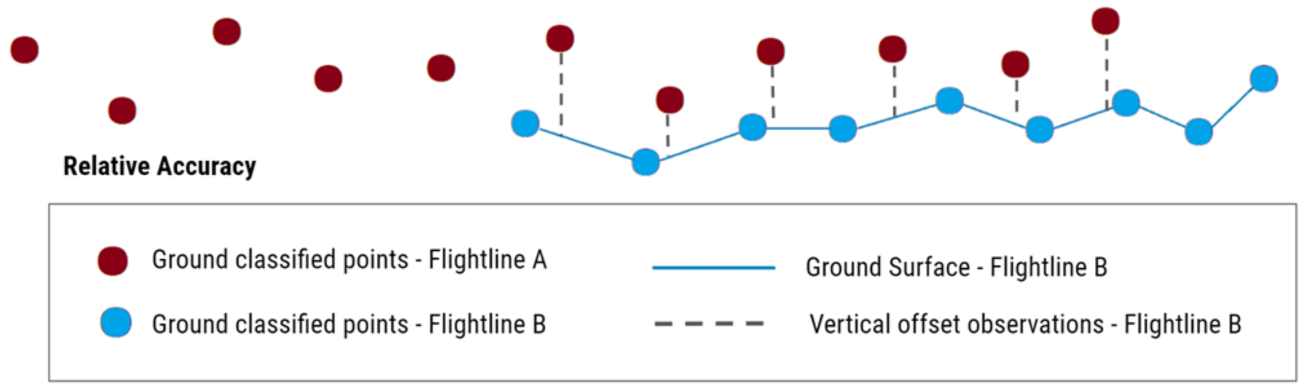
Relative Accuracy

Relative accuracy, also known as “swath-to-swath accuracy” or “interswath consistency”, is the measurement of how well overlapping areas of data collection match each other.

For LIDAR datasets, although offsets may occur in any direction, we measure this in vertical only.

Relative accuracy is influenced by lots of factors, many of which can be modeled and corrected.

Relative accuracy statistics are highly dependent on mission specific properties, such as trajectory quality, boresight quality and software / workflow employed, and are typically an indicator of those factors.

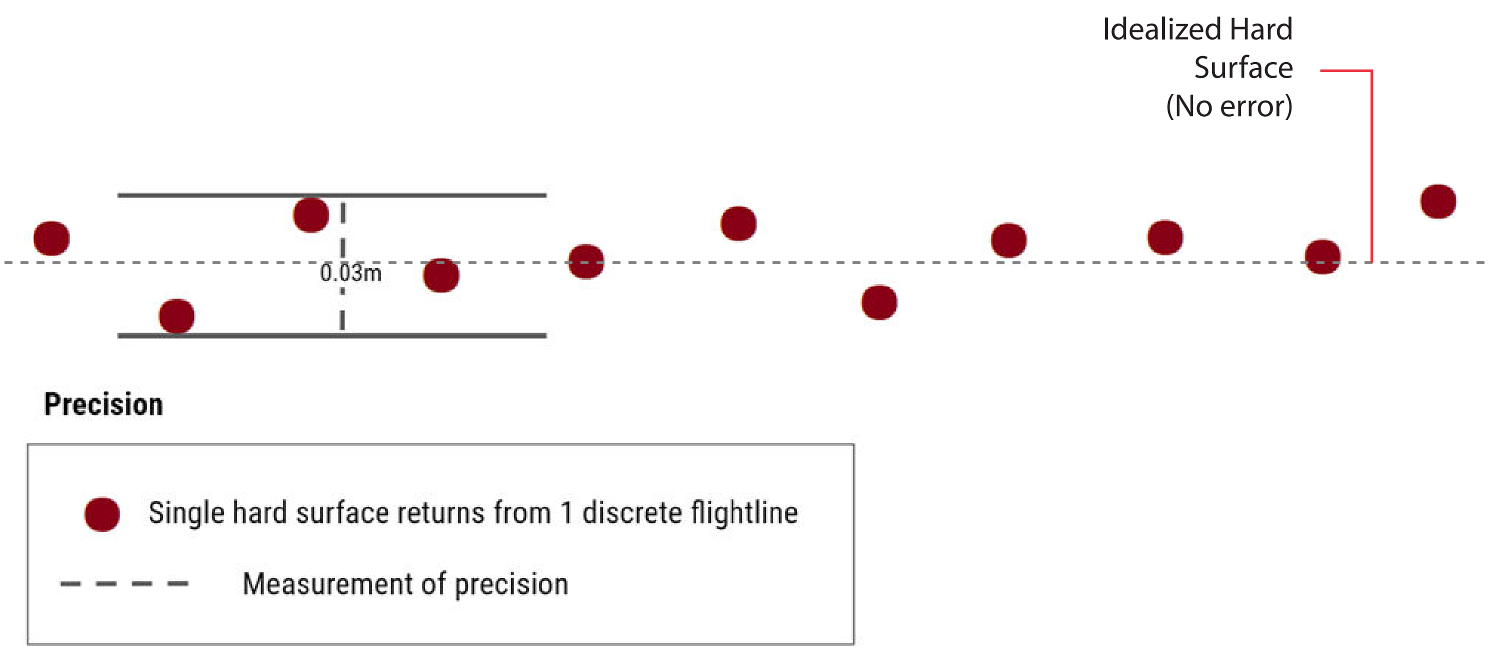


LiDAR Technical Specifications

Precision

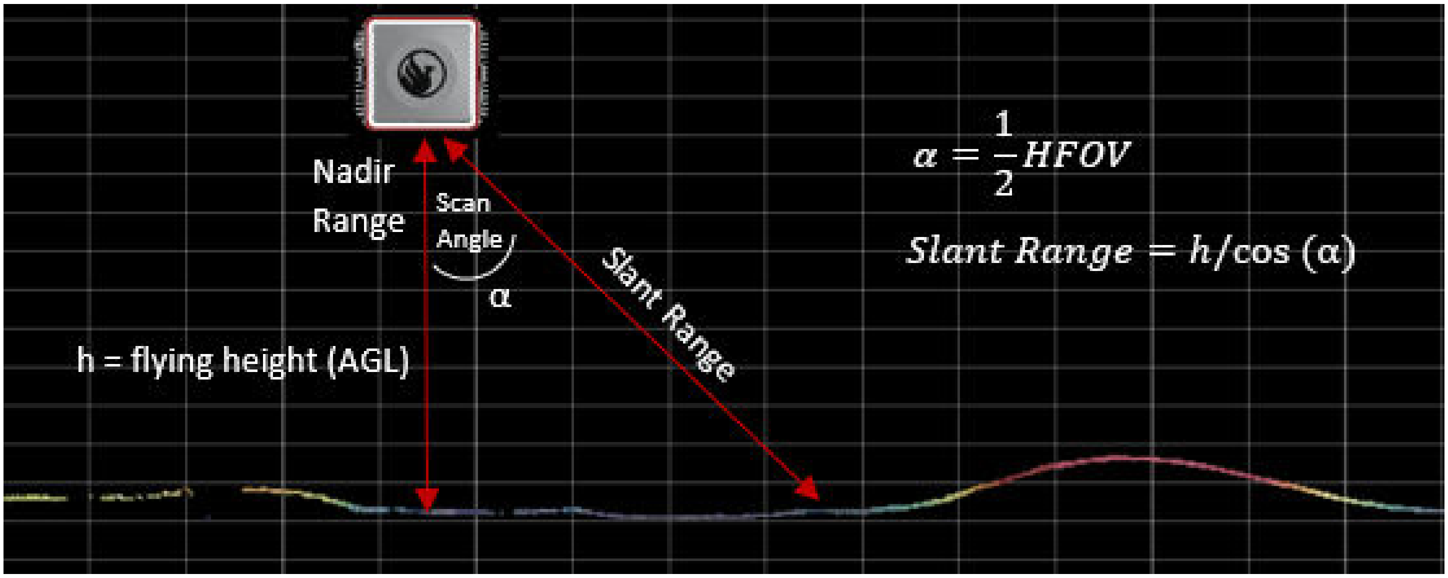
Precision, also called intraswath-precision, is a measurement of repeatability on a hard surface target from within a single pass of a scanner.

This metric is primarily a factor of the intrinsic calibration and stability of a scanner. It is also greatly impacted by properties of the measured surface.



Range Considerations

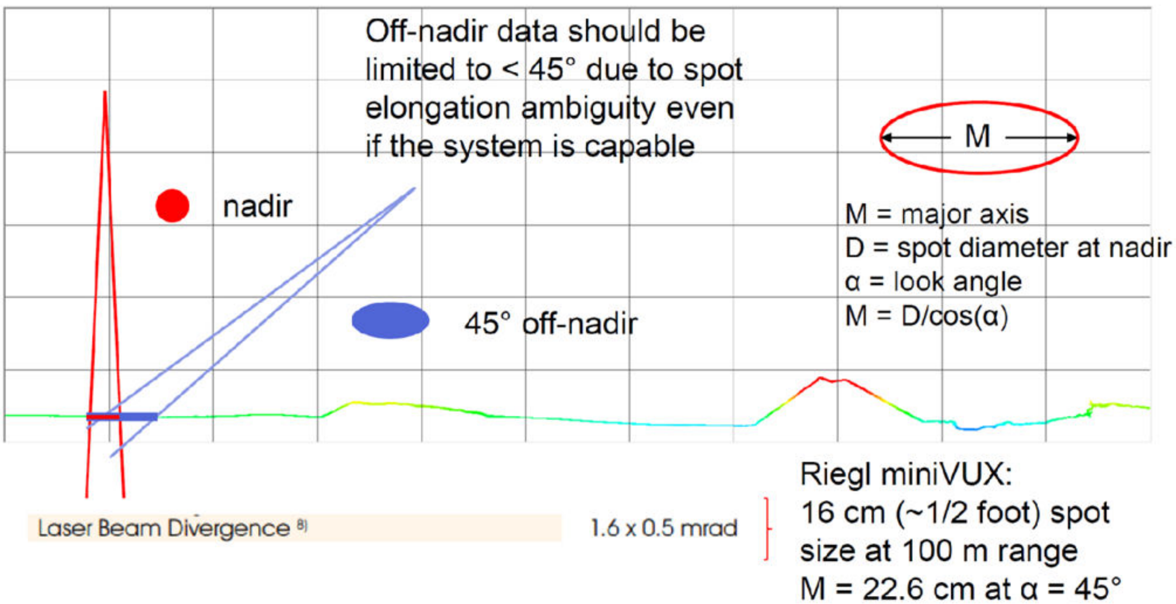
Maximum Range vs. Maximum Flying Height



- Maximum Range of sensor is a measure of the maximum Slant Range achievable.
- Max flying height, or AGL height, of a sensor and is a measure of NADIR Range

Impacts of Beam Divergence and Off-NADIR Accuracy

The beam divergence describes the widening of the beam over distance traveled. It is defined in milli-radiant (mrad), which usually describes a part of the circumcircle.



Vux 120 vs Vux 1 LR
Nadir sensor vs 360 sensor
ground survey vs multipurpose that can do survey and facade capture

Scout 16	3.0 mradbeam divergence.	About 30 cm at 100 m AGL NADIR*	M = 42.5 cm at 45°Δ 12 cm
MiniRanger	0.8 mradbeam divergence.	About 16 cm at 100 m AGL NADIR	M = 22.6 cm at 45°Δ 6 cm
RANGER UAV	0.5 mradbeam divergence.	About 5 cm at 100 m AGL NADIR	M = 7.1 cm at 45°Δ 2 cm

Platform and Configuration Overview

- Aerial
- Drone
- Mobile
- Handheld
- Cross Functional

While many LIDAR out there can be cross platform functional, it is important to select a platform that allows your lidar sensor to fully deliver the data required.

- Aerial Platforms are used for wide area or long range capture. While aircraft are used for high altitude wide area collections. Helicopters can also be used but these are typically used at much lower altitudes and slower speeds for corridor and infrastructure mapping where high point density is required.
- Drone LIDAR is the fastest growing sector in the market today. With sensors becoming lighter and smaller a drone can be used for many applications including on-demand mapping operations for 10 to 500 acres or corridor work from 1 to 5 miles. Due to c urrent FAA Beyond Line of Sight Regulations, projects larger than this are more cost effective using manned aerial platforms.
- Mobile Lidar invoves attaching LIDAR to a wheeled vehicle. While the other methods above look down to map, mobile LIDAR looks down and outward. This allows for more detailed reality capture of roads defects and side capture of infrastructure such as bridges and buildings.
- Hand Held or backpack is one of the newest mobile LIDAR technologies on the market today. Usually these systems incorporate some form of SLAM or GPS denied technology which allow the user to work under dense vegetation, inside buildings, or in dense urban environments where GPS may be can become unreliable
- Cross Functional. In many cases speciality LIDAR configurations are the way to go. Certain collection platforms with specific LIDAR sensors are essential for efficient data collection and to meet specific specifications. However for a small business that is developing its lidar business or is doing LIDAR on demand capture, cross functionality offers competitive opportunities and higher equipment return on investment possiblities.

Aerial Mounting System

Cessna Pod with a Ranger XL

Merkle mount with Ranger Ultra

Aerial mounted lidar system allow large area collection. Aircraft lidar pods and helicopter mounts are critical components for aerial surveying and mapping missions. These devices provide a high level of accuracy and precision for terrain mapping, infrastructure modeling, and other critical applications.

Aircraft lidar pods and helicopter mounts must comply with industry standards and regulations, including Federal Aviation Administration (FAA) regulations and aircraft certification requirements. These devices must be certified to the airframe. These requirements ensure reliability and public safety during flight operations.

One crucial consideration for these devices is vibration reduction. Helicopter mounts, in particular, must be designed to absorb the vibration caused by the rotor blades. In addition to vibration absorption many lidar systems incorporate advanced stabilization technologies, including high end IMUs to compensate for aircraft vibration. These technologies help to ensure that the lidar data is accurate and free from errors caused by aircraft movement.

PRIMARY DRONE LIDAR SENSORS

	RANGER ULTRA	RANGER LR	MINIRANGER 3	RECON XT
				
Accuracy	25-50mm	15-30mm	20-30mm	30-50mm
Range	760m	400m	290m	85m
Max Point Density (pts/s)	1800k	1500k	300k	640k
Returns	5-15	5-15	5	2
FOV (forward/horizontal)	FNB / 100°	- / 360°	- / 360°	20°/ 360°
Standard Camera	A7R4 Lite (43MP)	A7R4 Lite (43MP)	A6 Lite (24MP)	A6 Lite (24MP)

There are a lot of of considerations when selecting a lidar system.

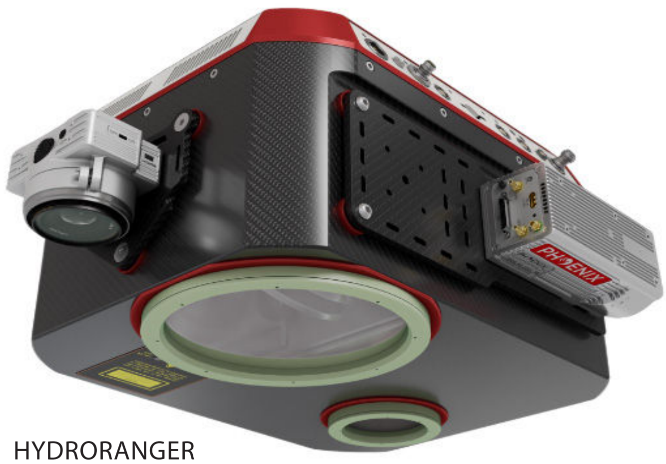
While there are many applications, the level of vertical precision is the driving factor. All professional sensors should have at least a 6 inch contour interval rating and 3 returns for advanced vegetation penetration to meet 90% of the usecases being done today.

From here the precision and accuracy are your primary consideration. As a company takes on more professional or federal projects, higher performance sensor will be required to meet contract requirements

Next consideration is point density. If you are doing anything with medium vegetation, just a few points will do. However once you start to increase the amount of vegetation or have higher resolution requirements, then you will want to consider higher point density. This will allow more opportunity to penetrate vegetation canopy and capture ground features.

Versilitiy and Field of View (FOV). When starting out and a company has not refined its usecases, it is best to start with a 360 degree FOV sensor. This allows the user to operation on a drone, truck, or handheld device. If the intent is to also cross over to aircraft, then range is also a consideration. 360 degree FOV are good for both topography and fascades like buildings and infrastructure. However as a firm increases demain for vetical precision in topography applications it is recommend to go with limited FOV lidar system to reduce errors due to angular error and beam divergence.

Specialty - Underwater Mapping Bathometric Lidar



HYDRORANGER

Bathy lidar, also known as airborne lidar bathymetry (ALB), is a technology that uses laser beams to map the depth of the ocean floor. It is a powerful tool for surveying underwater environments and is commonly used for applications such as coastal zone management, hydrographic surveying, and marine geology.

Bathy lidar works by emitting laser pulses from an aircraft or drone towards the ocean surface. The laser, sometimes referred as a green laser due to its specific green wavelength, penetrate the water, bounce off the seafloor, and return to the sensor. This allows the technology to create a high-resolution map of the underwater topography. Despite its many benefits, there are some limitations to bathy lidar technology. One of the main limitations is that it requires clear water to function effectively. Depending on power levels and turbidity these sensors can penetrate 2 Secchi depth below the surface. Secchi depth refers to the depth at which a disk lowered into the water can no longer be seen from the surface. Secchi depth is related to water clarity and is a measure of how deep light can penetrate into the water.

Despite its limitations, bathy lidar is being used for a variety of applications today. One popular use case is in coastal zone management, where bathy lidar can be used to map the topography of the seafloor and monitor changes due to erosion or sedimentation. It is also being used in hydrographic surveying for charting purposes, and in marine geology to study underwater volcanoes and other geological features.

Overall, bathy lidar is a valuable technology for mapping the ocean floor, providing scientists and decision-makers with important data to better understand and manage our oceans.

Software Considerations

Not everything is the same under the hood.

With all the new entries into the market the biggest differentiator between lidar integrators is software. While many will follow similar steps, the more established integrators tend to add features that allow for increased accuracy, more data capacity, and streamlined workflows.

Basic Lidar Workflow

The basic lidar workflow consists of geographic referencing, telemetry correction, Lidar fusion, and colorization to generate an RGB geo-referenced point cloud. The first step is to enter the coordinates in for the reference base station. This is important as this corrects for GPS error and assigns the data to a known coordinate and reference system. For US surveyors and engineers this can be the most important step as this will allow your data to sync with other data sets. Many foreign systems or startup companies do not have this feature and can create a lot of work getting the data into the right reference system. Next the GPS and IMU data is calibrated to trace the path of the lidar. Some system uses advanced algorithms to smooth the data and remove erroneous positional outliers that can affect accuracy of the product. Finally, the lidar and imagery are fused with the telemetry to generate your point cloud.

Advanced Considerations (Data Conditioning)

Anyone that has been doing lidar for a while can tell you that there are always little errors that can be improved on. Here is a list of things you should consider having in your data conditioning workflow:
Strip Matching – As time progresses during the flight or in between flight, small vertical bias start to form. Strip matching samples the different swaths of data to ensure they produce a highly accurate smooth surface across the project site.
Outliers – This process removes random noise in your data set.
Classification Tools – This is a set of tools that help segment your data into objects or groups. Really important if you want to know just the ground for land survey. However you can also classify buildings, levels of vegetation, powerlines and more. See ASPRS Lidar 1.4 Specifications.
Ground Control Adjustments – This allows you to make adjustments between surveyed points and lidar data.
Export Tools – if you are using 3rd party software to do your survey or engineering work, you should be able to export in the appropriate file format.

Contact us to know more

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Monday-Friday

9:00 am – 5:00 pm CDT