**VISVESVARAYA TECHNOLOGICAL UNIVERSITY Belgaum-590018, Karnataka**



**A SEMINAR REPORT**

ON

# “LIDAR-Light Detection and Ranging”

Submitted in partial fulfillment of requirements for the award of degree, **BACHELOR OF ENGINEERING**

**IN**

**COMPUTER SCIENCE & ENGINEERING**

Submitted By:

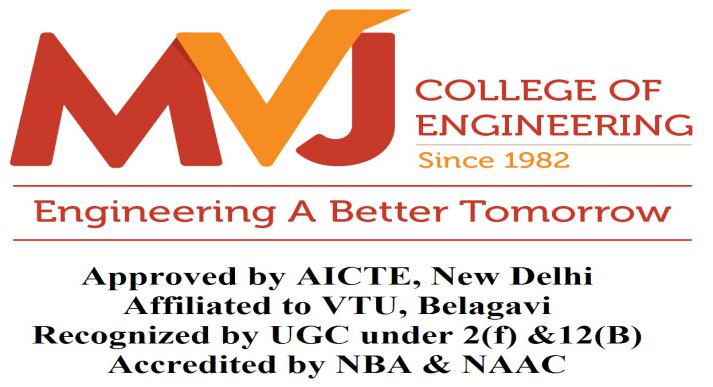
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**ABSTRACT**

Lidar uses ultraviolet, visible, or near infrared light to image objects. It can target a wide range of materials, including non-metallic objects, rocks, rain, chemical compounds, aerosols, clouds and even single molecule. A narrow laser beam can map physical features with very high resolutions; for example, an aircraft can map terrain at 30-centimetre (12 in) resolution or better.

Basic time-of-flight principles applied to laser range-finding

Flying over the Brazilian Amazon with a LIDAR instrument.

Animation of a satellite collecting digital elevation map data over the Ganges and Brahmaputra River basin using lidar.

The essential concept of lidar was originated by EH Synge in 1930, who envisaged the use of powerful searchlights to probe the atmosphere. Indeed, lidar has since been used extensively for atmospheric research and meteorology. Lidar instruments fitted to aircraft and satellites carry out surveying and mapping – a recent example being the U.S. Geological Survey Experimental Advanced Airborne Research Lidar. NASA has identified lidar as a key technology for enabling autonomous precision safe landing of future robotic and crewed lunar-landing vehicles.

Wavelengths vary to suit the target: from about 10 micrometres (infrared) to approximately 250 nm (UV). Typically, light is reflected via backscattering, as opposed to pure reflection one might find with a mirror. Different types of scattering are used for different lidar applications: most commonly Rayleigh scattering, Mie scattering, Raman scattering, and fluorescence. Suitable combinations of wavelengths can allow for remote mapping of atmospheric contents by identifying wavelength-dependent changes in the intensity of the returned signal.

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**CHAPTER 1**

**INTRODUCTION**

Light detection and ranging (lidar) mapping is an accepted method of generating precise and directly georeferenced spatial information about the shape and surface characteristics of the Earth. Recent advancements in lidar mapping systems and their enabling technologies allow scientists and mapping professionals to examine natural and built environments across a wide range of scales with greater accuracy, precision, and flexibility than ever before. Several national reports issued over the past five years highlight the value and critical need of lidar data. The National Enhanced Elevation Assessment (NEEA) surveyed over 200 federal, state, local, tribal, and nongovernmental organizations to better understand how they use enhanced elevation data, such as lidar data. The over 400 resulting functional activities were grouped into 27 predefined business uses for summary and benefit-cost analysis (NDEP, 2012). Several of these activities will be described in more detail in the applications section of this document. There are many considerations and trade-offs that must be understood in order to make sound decisions about the procurement, processing, and application of lidar data. This document provides introductory and overview information, as well as in-depth technical information, to support decision-making in all phases of lidar projects. While the information presented here is not comprehensive, it covers aspects of the technology that are the most common subjects of discussion within the coastal management community.

Lidar has become an established method for collecting very dense and accurate elevation data across landscapes, shallow-water areas, and project sites. This active remote sensing technique is similar to radar but uses laser light pulses instead of radio waves.

**CHAPTER 2**

**Literature Review**

**2.1History**

In 1930, E.H. Synge was the first to suggest that atmospheric density measurements could be obtained by analyzing the light return scatter obtained from searchlights that illuminate the sky [4]. Early lidar systems, such as the type proposed by Synge, operated in a biaxial configuration that allowed range-resolved measurements. In a biaxial setup, the lidar detector is located some distance (up to several kilometers) away from the point where light is transmitted to the atmosphere. The receiver’s field-of-view (FOV) can be scanned along the searchlight beam to obtain a height profile of the scattered light’s intensity by applying simple geometry. Figure 1 illustrates the biaxial setup as well as other configurations that will be discussed later. Figure 1: Lidar Design Configurations Six years later, in 1936, Decalux was able to acquire atmospheric density measurements at an altitude of 3.4 km by applying the method that Synge proposed [5]. Hulbert later extended this work to obtain measurements at 28 km [6]. Further developments in lidar technology introduced the monostatic configuration where the transmitter and receiver are grouped together in a monostatic-coaxial or monostatic biaxial arrangement, shown above in Figure 1. This design improvement allowed lidar systems to incorporate transmitters that pulse the light source, thereby permitting the measurement of round-trip time of flight of the scattered light pulse. In 1938 Bureau was the first to use a pulsed, monostatic system to determine cloud base heights which signaled the birth of range-resolved lidar measurement techniques as we know them today [7].

**2.2Early Application**

LiDAR systems were developed back in the 1960s and found their first applications predominantly in terrain mapping of aeronautics and aerospace. During the 70s, remote sensing based on lasers concentrated on airborne sensor deployment where topographic mapping of forests, ice sheets, oceans and the atmosphere was conducted. What most people certainly don’t know, under Apollo 15, NASA were to apply the scanning technology for surface mapping purposes of the moon.

LiDAR development proceeded in slow pace. Until the 80s, the dissemination of LiDAR’s was throttled due to a lack of commercial GPS systems required to foster aerial sensor deployment. When GPS solutions and efficient satellite communication for data transmission later came up, aerial photogrammetry was enabled and the way for widespread aerial LiDAR employment was smoothed. In the following years, due to its outstanding resolution, LiDAR became especially popular for calculating precise geo data as well as for deployment in meteorology and atmospheric research. The laser light’s short wavelength which enables detection of tiny objects such as particles of clouds and aerosols is crucial for airborne and terrain mapping.

**CHAPTER 3**

**Problem Analysis**

**3.1 Capabilities and Limitations**

Capabilities and Limitations a. Capabilities. LIDAR mapping to ground control station is needed within 30 km of the project/collection site. Depending on the flying height, swath width, scan angle, and scan and pulse rates, the shot spacing can range from 25 points per square meter to one point every 12 m (144 sq m). LIDAR is ideal for corridor mapping projects and can provide accurate information for shoreline/beach delineation. Laser mapping is feasible in daylight, overcast (if clouds are above the aircraft platform), or nighttime operations. Day time collection is not dependent upon adequate sun angle as is conventional aerial photography. Several vendors have developed algorithms to classify and remove vegetation to produce bare earth models of the data where some of the LIDAR data points are able to penetrate the vegetation cover. b. Limitations. LIDAR sensors can only collect during cloud coverage if the cl h cannot collect data in rain, fog, mist, smoke, or snowstorms. In areas of dense vegetation coverage, the LIDAR pulses, in most cases, will not be able to penetrate through the foliage to the ground unless ample openings in the vegetation exist and the spot size of the pulse is small and densely spaced. Imagery data (digital photos or satellite imagery) are needed to perform proper vegetation classification and removal when producing bare earth models from multiple return LIDAR data.

**3.2 Comparisons with Existing Technologies**

1. *Photogrammetry.* The use of LIDAR for topographic mapping and collection of elevation data compares very well with competing technologies, such as traditional aerial photogrammetry, especially in areas where the LIDAR pulse can penetrate foliage. Not only does the data collection compare well, but

the data processing of LIDAR, because it is simple X, Y, Z point data, can be more automated with minimal user interaction, unlike photogrammetric processing which requires a lot of user interaction. Table 11-1 lists the comparisons between LIDAR and traditional photogrammetry on some of their basic parameters. In many cases, photogrammetry (usually digital photography) is used in conjunction with LIDAR bare earth processing techniques.

**Table 11-1**

**Comparison between Lidar and Photogrammetry**

**LIDAR Photogrammetry**

Energy source Active Passive

Geometry Polar Perspective

Sensor type

Point measurement

Point Frame or linear scanning

Direct Indirect

Sampling Individual points Full area

Associated image

None or monochrome

High quality spatial and radiometric

Horizontal accuracy 2-5 times less than vertical accuracy 1/3 better than vertical

Vertical accuracy

10-15 cm (~10 cm per 1,000 m over heights of 2,500 m)

Function of flying height and focal length of camera

Flight planning More complex due to small strips and potential data voids

Flight restrictions Less impact from weather, day/night, season, cloud

condition

Production rate Can be more automated and faster

Budget 25%-33% of photogrammetric compilation budget

Overlap and side lap need to be considered

Must fly during day and need clear sky

Production

Proprietary software: processing performed by vendors,

Desktop software available to end-

operator’s user

Limited contrast area acquisition

Can acquire data: used extensively for coastal mapping

Difficult and expensive

*Radar technologies.* LIDAR can provide higher accuracy and more detailed information about

the landscape than radar technologies such as Interferometric Synthetic Aperture Radar (IFSAR).

Elevation data obtained from IFSAR is collected in a side-looking mode, that is, off to one side, which can result in data voids in non-open areas. LIDAR data are collected 10-20 deg either side of vertical to minimize data void areas and to collect direct vertical measurements to the ground or tops of features. IFSAR, however, can fly higher to obtain larger areas in shorter periods of time and is not affected by cloud cover. Current investigations are examining the benefits of combining IFSAR and LIDAR for use in enhancing the strong points of both systems.

# 3.4 Contracting Issues

A Contractor should provide experience in the production of the type of data required for a project. Quality control data for LIDAR projects is imperative. A Contractor should provide proof of quality of data collection for projects like that requested by a U.S. Army Corps of Engineers office. Quality control should include accuracy assessment of the final products and not simply the accuracy of individual point. The FEMA has a standard specification for LIDAR collection and processing. The FEMA specifications can be accessed on the FEMA web site. These specifications may be used in conjunction with or referred to in a SOW for a photogrammetric mapping project that will utilize LIDAR technology.

It is important for a project that might involve using LIDAR to state the accuracy of the final products in terms of DEM, Digital Terrain Model (DTM), or contours produced with the LIDAR data. For example, the accuracy should be stated in terms like “The final DTM produced will be of a quality that will meet or exceed ASPRS Class I Standards for the production of 1-foot contours.” The ASPRS Standards allow for hidden (dashed contours) in areas where the ground is obscured, since data collected with LIDAR may have such areas.

LIDAR data collection can offer scheduling and cost advantages over labor-intensive air photo mapping because it offers rapid data collection and fast postprocessing. Estimating the cost of LIDAR data collection is not standardized at this time. Only a few firms have the equipment and capability to collect the data, thus creating a varied market value. Cost can vary significantly based on the size, time of year, and location of a project. For some projects where elevation data are very critical, very large-scale mapping LIDAR may be cost prohibitive.

**CHAPTER 4**

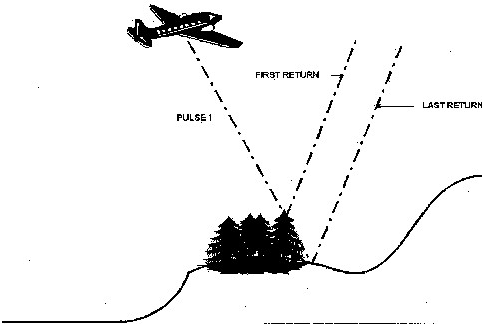
**Implementation**

# 4.1 LIDAR System Components

There are four basic components of a LIDAR system. The system includes the laser and scanning subsystem, GPS, IMU, and the operator and pilot display for flight navigation. Many systems also have an integrated digital camera to provide digital images used in bare earth modeling algorithms and feature classification procedures. Some systems have an integrated video camera to record the area scanned by the laser.

1. *LIDAR sensors.* The types of LIDAR sensors used for topographic applications operate in the near infrared band of the electromagnetic spectrum whereas those used for bathymetric applications operate in the blue/green band. The majority of the sensors on the market today all perform the same way in that they measure distances from the sensor to the ground or desired feature. The differences in the systems are in the power of the laser, the spread of the beam or spot size, swath angle, and the number of pulses per second transmitted. Several systems on the market today also have the capability of

measuring multiple returns of each pulse sent out and the intensity of the return. Multiple returns are beneficial in areas of sparse vegetation or tree cover where the first return would hit the top of the tree and the last would penetrate down to the ground. First and last return sensors in some instances may provide bare earth models with less manual editing. See Figure 11-3 . Projects that require “bare earth” data collection should define the term “bare earth.” Employing LIDAR technology to develop bare earth models is not standardized. Care should be taken in development of a scope of work to ensure a complete understanding between all parties of the intended use of the data sets. This should include sufficient definition of terms such as bare earth and reflective surface models, etc. Typical sensor characteristics are listed in Table 11-2.



**Figure 11-3. First and last return sensors (courtesy of Atlantic Aerial Technology)**

**Table 11-2**

**Typical Sensor Characteristics**

|  |  |
| --- | --- |
| **Parameter Typical value(s)**  Vertical accuracy (cm) 15 | |
| Horizontal accuracy (m) | 0.2 - 1 |
| Flying height (m) | 200 – 6,000 |
| Scan angle (deg) | 1 – 75 |
| Scan rate (Hz) | 0 – 40 |
| Beam divergence (mrads) | 0.3 – 2 |
| Pulse rate (KHz) | 05 – 33 |
| Footprint diameter (m) from 1,000 m | 0.25 – 2 |
| Spot density (m) | 0.25 – 12 |

1. *GPS.* The GPS component provides timing and positional information to the LIDAR system. The LIDAR pulses are time tagged using the time from the GPS receiver to later correlate them with the GPS solution summary. The type of GPS receiver used within the system should be capable of measuring/collecting the L1/L2 carrier phase data at a rate of 1 Hz (1 measurement per second). The same type of GPS receiver is required for ground control stations. The processing of the GPS data

between the receiver onboard the aircraft and the receiver(s) on the ground control station(s) is known as On-The-Fly (OTF) Differential GPS. OTF, also referred to as Kinematic OTF or Real-Time Kinematic (RTK), allows for high-accuracy (<10-cm) 3-D positioning of a moving platform without static initialization.

1. *IMU*. The inertial measurement unit measures the LIDAR system orientation in roll, pitch, and heading. These values are combined with the GPS positional information and the laser range data scan values with rigorous geodetic calculations to yield the X, Y, Z of the points collected.
2. *Operator and pilot displays.* The operator display provides valuable information as data are being collected to the operator on the number of measurements returned, the status of the GPS satellites, IRS, and laser sensors, and the progress of the aircraft along the flight line. The pilot has a display of the aircraft along the flight line path with left/right/elevation indicators. This allows the pilot to navigate along the preprogrammed flight line.
3. *Digital imagery/video.* In some systems, a digital camera is used to provide an image of the areas being collected. The X,Y,Z data from the LIDAR can be overlaid on this imagery and used in the classification process. On a few systems, a down-looking video camera may also be mounted next to the laser and used to record the area scanned by the laser sensor. Time, latitude, and longitude are usually recording as part of the video display. This information is used by the operator to view the area being collected during the flight as well as used in post processing of the LIDAR data. The audio portion of the recording is used by the operator to note items or features of interest.

# 4.2 Planning a LIDAR Data Collection

There are several items, which need to be known when planning a project where LIDAR can be used, including when a collection should take place and requirements for ground control.

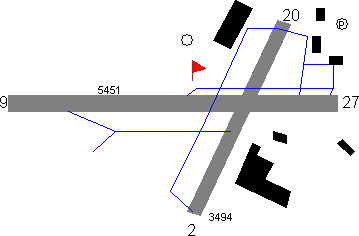
1. *General.* The bounding coordinates of the project area need to be known since it is critical in searching for control and setting up the flight lines to be used during the data collection. The type of area where the data collection will take place needs to be examined for amount of vegetation, trees, buildings, and other features that might impact the data collection. For example, if a bare earth elevation model is the product, then there must be adequate spacing between the vegetation cover to allow the laser pulse to penetrate and obtain ground elevations. A bare earth DEM from LIDAR data in vegetated areas may also require a system with a higher scan rate, slower flying speed, smaller beam angle, or lower flying altitude to obtain a denser point spacing and have the laser pulses penetrate to the ground.
2. *When to collect.* Unlike photogrammetry, LIDAR data collection is not affected by sun angle and does not require collection to be performed in late fall or early spring for leaf-off conditions. However, it is advantageous to collect LIDAR data during leaf-off conditions in areas with dense deciduous trees, especially when the end requirements are for a bare earth DEM. Since the positioning of the LIDAR sensor relies on the GPS, specifically the kinematic solution of L1/L2 carrier phase processing, satellite ambiguity resolution must occur from data collected during times of low Position Dilution of Precision (PDOP), less than five, and with a minimum of five satellites. Most GPS postprocessing packages include mission planning software for checking PDOP and the number of satellites available for a specified time. See EM 1110-1-1003, “NAVSTAR Global Positioning System Surveying,” for more information on data collection with GPS and DGPS.
3. *Ground control.* The project ground control consists of the base stations, calibration control, and the project area control. All control throughout the project should be tied to a single geodetic network for consistency, blunder detection, and overall reliability. All GPS measurements should be made where the carrier phase (L1/L2) data are collected at each station and postprocessed using geodetic techniques. If

orthometric heights are required as the result, it is important that control points be used that have known North American Vertical Datum of 1988 (NAVD 88) heights for proper geoid modeling. See ETL 1110-1-183, “Using Differential GPS Positioning for Elevation Determination,” for additional information on performing geoid modeling. A good source for locating high-accuracy control points in your project area is the National Geodetic Survey’s (NGS) on-line data sheet search [(www.n](http://www.ngs.noaa.gov/)g[s.noaa.gov,](http://www.ngs.noaa.gov/) click on Data Sheets). Control points can be searched for in multiple ways (radial from project center, by USGS quad, bounding coordinates, …). Reconnaissance of control to be used should be done prior to data collection to make sure that control still exists and has no obstructions for satellite visibility.

1. Base stations: These control stations must be within 30 to 40 km of the project area. In some case, the base station is set adjacent to the aircraft at takeoff and landing. The aircraft unit is initialized with the aircraft on the ground and stationary; following a brief initialization period the aircraft flies the project, then returns to the same location for a brief stationary period prior to closing the GPS session. Some vendors also collect data from two base stations to provide redundancy and backup in case one of the GPS receivers fails. By initializing the GPS ambiguities with the aircraft and base station receivers in proximity, the ambiguity (hence GPS solution) may be carried over very long ranges. A conservative recommendation is a 50-km distance between the base station and the project site. Using a minimum of two points will also allow for processing between stations for a check on control. It is important that the control points used have the required horizontal and vertical accuracy to meet the need of the project accuracy.
2. Calibration control: To make sure the LIDAR system is working properly; a calibration site may be established at or near the project site. Usually, this calibration site is established at the airport where the plane begins the data collection mission. This requires additional calibration control at the airport as shown in Figure 11-4. The aircraft would fly over the airport immediately following takeoff to calibrate, or confirm calibration, of the total system.
3. Project area control: The project area control is utilized to test the accuracy of the system and the final products. The quantity of control points is totally project dependent on the project and must consider the vegetative and terrain types in the project area. Selection of the control locations should give consideration to the fact that, in dense vegetation or steep terrain, errors in the final products may be functions of the slope or vegetative characteristics and not the LIDAR system itself.

# 4.3 LIDAR Data Collection

1. *Calibration and quality control.* Successful processing of LIDAR data normally requires both system calibration and quality control data collection. These requirements should be included in flight plan instructions to the flight crew. The following calibration and quality control requirements should be designed into each flight.
2. Airport bidirectional and cross flight lines. A bidirectional and cross flight should be conducted over the airport for every flight using project specific parameters. The minimum critical parameters include altitude, field of view, scan and pulse rate, and aircraft speed. The results from this data set can be used to verify the accuracy of the system for the mission, and/or to make final adjustments to the calibration values used in the computations.
3. Project cross flight lines. A cross flight line is a line that is perpendicular to and intersects the job flight lines. The primary function of the cross flight is to detect systematic errors such as a false increase in elevation of data away from nadir or line to line, detection of anomalies in individual lines, and to demonstrate the repeatability of results. It is important for these lines to cross all project flight lines. To provide the maximum information content, the cross lines should intersect the primary job lines in clear open areas with no vegetation, if possible.



**Scheme for LIDAR Airport Control Points**

Bidirectional Flight line

Cross Flight line

= 12 Building Corners

= 8 GC Points

Max 2500 ft from Center of Runway

**Figure 11-4. Airport calibration control scheme (courtesy of Earth data International)**

1. Calibration site and project ground control. A series of geodetic ground control points at the airport calibration site and throughout the project are required for a complete quality control plan. Although LIDAR is very consistent between individual measurements, it is simply a two-way ranging system and is therefore susceptible to bias. To detect and correct for any bias, and as an overall quality check of the data, a series of control points should be established at the project airport as shown in Figure 11-4 and throughout the project site.
2. *Base station ground control.* Since positioning of the LIDAR sensor will be performed relative to the ground control stations used, proper setup and configuration of the GPS antennas and receivers is very important. This includes using tripods and tribraches or fixed-height tripods that are calibrated and plumbed properly and receivers that are configured to collect at the same measurement rate as the receiver connected to the LIDAR sensor. GPS receiver/antennas should be set up and collecting L1/L2 carrier phase data prior to the aircraft’s entering the data collection area.
3. *LIDAR collection.* Once the system is configured and flight lines are established, the operator monitors the progress of the data collections to ensure data are being received back to the sensor. In almost all cases, the system operator will know if the laser is working correctly because lasers work or do not work. The operator can watch for erratic data from the IMU and the GPS to determine if those systems are working correctly. In general, flight lines are created to provide a 30-percent overlap of the previous flight line collection swath with the current line’s swath. All the LIDAR returns are GPS time- tagged to correspond with the postprocessed DGPS solution.

**CHAPTER 5**

**LIDAR Data Processing**

1. Once the data are collected, the first step is to download the GPS carrier phase data from the control station and the aircraft receivers. These data are then input into the GPS postprocessing software package to compute the high-accuracy kinematic solution trajectory of the aircraft (Figure 11-5). There are several vendors that produce GPS processing software capable of this type of processing. The trajectory is then merged with the IMU data for a complete position and orientation solution. The laser ranging data are then merged, using geodetic algorithms, to the position and orientation to derive the end result, a X, Y,Z position for each pulse return measured by the sensor.

A computer screen capture

Description automatically generated with low confidence

**Figure 11- 5. DGPS processed trajectory of aircraft (courtesy of Rapid Terrain Visualization Program)**

1. During data processing, a quality control review must examine the data for anomalies, systematic

errors, or any potential horizontal or vertical bias. These anomalies could be a result of misalignment in any axis (roll, pitch, or yaw), system timing offsets, atmospheric conditions, GPS bias, or extreme spectral conditions of the natural terrain scene. Each of these anomalies can be detected with careful review and generally resolved in the data processing if required.

# 5.1 Results

1. *Raw LIDAR data.* Raw LIDAR data sets are simply a mass of X, Y, Z points for the object that the laser hits, measures, and records the distance to. The points are processed and referenced to the datum requested. See Figure 11-6.
2. A close up of a person's face

   Description automatically generated with low confidence*Contour plots.* The point data itself may or may not be of sufficient quality for a project. Often the product required is contours of the earth surface. The accuracy requirements for the contours may require the collection of aerial imagery to assist in the collection of mass points and break lines in the

**Figure 11-6. Raw LIDAR data (courtesy of Atlantic Aerial Technology)**

locations required to adequately depict the character of the earth surface. Note, the sensor generally cannot see through dense vegetation or structures. In areas such as these, other tools such as ground surveys will be required to supplement LIDAR data sets and can add to the cost. When contours are required, the scope of work should state an expected accuracy according the ASPRS Standards as indicated in Chapter 2. LIDAR is simply one of the many tools that may be used to generate an elevation model. Other tools may be required in conjunction with LIDAR data to generate the type of products requested.

1. *Surface modeling.* These data from the sensors also may provide easy surface model generation. Surface model generation is accomplished by assigning colors or shades of gray to reflectance intensity from the sensor pulses. See Figure 11-7 and b. Care should be taken in using surface models generated from LIDAR data sets. Note, the points utilized in the model are collected at the first or last return of the pulse. This is not necessarily to the edge of a building, ground surface, etc. A LIDAR generated surface model does not have the accuracy of an orthophoto image.

# 5.2 Data Classification

To produce an accurate contour plot of the ground elevations or to develop surface models from LIDAR data, especially in non-open area (areas with trees, vegetation, structures, …), classification of these objects must be made in order to remove them from the final product. Most companies that provide LIDAR services have methods for performing data classification. Many of these methods are proprietary but all have the basic intention of identifying objects that are not ground features and need to be removed to develop a bald or bare earth model.

1. A screenshot of a video game

   Description automatically generated with medium confidenceA picture containing text, building, brick, old

   Description automatically generated **b.**

**Figure 11-7. Surface models generated from LIDAR data (courtesy of Atlantic Aerial Technology)**

# Application

1. **Agriculture** – LiDAR can help agriculture technology (AdTech) companies pinpoint areas with optimal sunshine for more efficient growing. It also can be used to train machine learning systems to identify crops that need water or fertilizer.
2. **Archeology** – This technology has revolutionized the world of archeology, helping experts discover hidden structures around the globe. There are two archeologists from the University of Colorado who are on a mission to scan the entire planet with LiDAR
3. **Astronomy** – NASA (U.S. National Aeronautics and Space Administration) used LiDAR technology to explore Mars. They were able to create a topographic map and detect snow falling in the atmosphere.
4. **Climate change** – Climate scientists use LiDAR to study and track changes in the atmosphere. Researchers in Germany have developed an airborne LiDAR system can track atmospheric gases and may even be usable from space. Botanists are using it to track patterns in changes to forested areas. LiDAR also is used to calculate changes in glaciers over time.
5. **Land management** – Land management organizations can monitor land resources in real-time, allowing for faster and more efficient mapping compared to aerial surveys. They also use it in disaster assessment, early warning systems, emergency response (e.g., to fight forest fires), and location-based investigations.

**Advantages and Disadvantages**

**Advantages**

### Accuracy

Above all, LiDAR technology offers incredibly accurate, consistent results. The short wavelength can even detect small objects and create exact 3D models, making it possible to determine what the objects are, whether it’s a tree, person, or wall.

### Speed

The sensor sends out laser pulses and receives them back in nanoseconds, making it possible to scan large areas in a fairly short period of time and still get a high volume of data.

### Can Collect from a Variety of Locations

Places that are inaccessible, such as high mountains, dense forests and hard to reach areas can be easily mapped with LiDAR technology.

### Automated Functionality

LiDAR technology consists of primarily automated processes, and while experienced pilots are necessary to operate the equipment, it’s more efficient than other methods of surveying that require more hands-on involvement.

### Low Cost

Given the speed and large area that can be scanned coupled with the highly accurate results, LiDAR is significantly less expensive than other methods of land surveying and mapping. It is an affordable way to produce complex topographical surveys.

**Disadvantages**

Speed, cost, and the sheer volume of highly accurate data tend to make LiDAR the right option, but it’s important to know the disadvantages as you plan its use.

### Requires Experience to Operate

It takes previous surveying experience to take check shots, run base stations, and check-in to benchmarks. The LiDAR is complex in nature and requires a deep understanding of the sensor.

### Purchasing High-End LiDAR Sensors Are Costly

If you are trying to set up your own LiDAR shop it requires heavy investment into the LiDAR sensor and the personnel.

**Ineffective during heavy rain or low hanging clouds:** LiDAR pulses may be affected by heavy rains or low hanging clouds because of the effects of refraction. However, the data collected can still be used for analysis.

**Conclusion**

While the lidar is a promising new advance for the wind energy industry, this report identifies the need for improvement in the following areas:

• More robust battery backup system

• More restrictive data validity requirements during cold temperature startup/operation

• Expanded averaging options when data are directly retrieved from the compact flash memory card

**References**

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