**1157 – Invesitage LIDAR Feasiblity**

**Content**

As a lab member, I would like to look into using lidar as a possible mapping payload for ARGO

**Definition of Done**

[ ] Look into the precedence of using Lidar on small UAV systems

[ ] Research possible applications of this technology

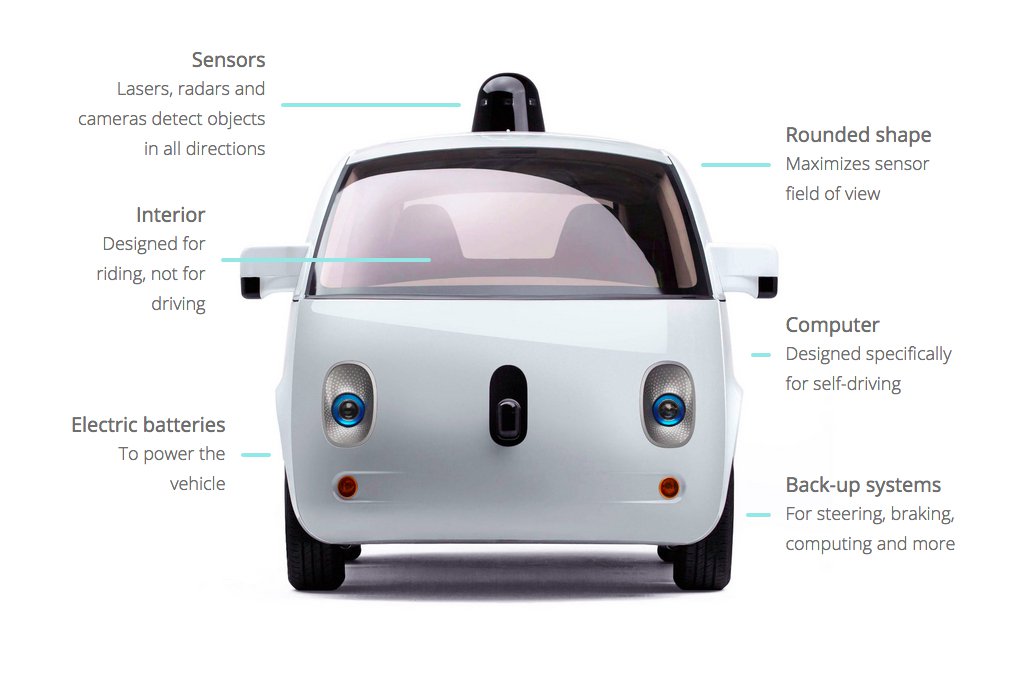
[ ] Discuss your findings with Dr. Lum, Connor, Zach and Scott

# Report

## Uses

**SpaceX's Dragon** to determine the range of the spacecraft whilst docking to the ISS

Unmanned Vehicles (**Google**’s Self Driving Cars/**Tesla**) - provide accurate information on the height and distance of objects.



Seems to be mainly suited for self driving vehicles, whether airborne or not.

Do not believe it is a priority to our laboratory, but would be a nice thing to invest in, assuming the financial assets for the laboratory is stable.

## General Uses

Lidar Sensors For Drone Collision Avoidance

Lidar Sensors For Ground And Above Ground Imagery

Lidar Drones For Structural Inspection

Lidar Sensors In The Night

Agriculture & forestry

Archaeology and cultural heritage documentation

Corridor mapping: power line, railway track, and pipeline inspection

Topography in open-cast mining

Construction site monitoring

Building and structural inspections

Surveying of urban environments

Resource management

Collision avoidance

Shoreline and storm surge modeling

Hydrodynamic modeling

Digital Elevation Models

## Possible Applications

**Micro-Topography**: LIDAR is very accurate and precise technology which uses laser pulse to strike the object. Regular photogrammetry or other survey technology can miss the surface elevation value that is hidden by vegetation or forest canopy. But LIDAR can penetrate through the object and detect the surface value.

**Agriculture**: LIDAR helps the farmer to find the area that uses costly fertilizer. LIDAR can be used to create elevation map of the farmland that can be converted to create slope and sunlight exposure area map. Both the layer information can be used to create high, medium and low crop production area. Extracted information will help farmer to save on the costly fertilizer.

**Environmental Assessment**: Micro topography data generated form the LIDAR data is used in the environment assessment. Environment assessment is done to protect the plants and environment. Remote sensing and surface information (LIDAR) is used to find the area that is affected by the human activities.

**Mapping**: Surface model created from LIDAR is used to add graphical value to maps. DEM (from LIDAR) is added underneath of all layers that shows the 3D view of the land. Especially LIDAR data (DEM) is added on the aerial photography to show the 3D view which makes easier to plan roads, buildings, bridges and rivers.

**Geology**: In geology the combination of LIDAR aircraft and GPS has evolved so much it is used finding the fault and measuring the uplift. The combination of above technology was used to find the Seattle fault in the Washington State, USA. NASA satellite called ICESAT that has LIDAR sensor is used to monitor glaciers and perform coastal change analysis.

**Imaging**: LIDAR technology is used to create 3D image of the object that is in distance. 3D imaging is done with both scanning and non-scanning systems. There is a technology which uses combination of fast gated camera and LIDAR to created 3D image (3D gated viewing laser radar). It is a non-scanning systems.

Also look into Multispectral and Photogrammetry Imagery

Lidar, multispectral and photogrammetry imagery are all fairly similar. Look into what the intentions for the UAV mappings are, then proceed on deciding on which one to integrate into ARGO.

Look intoFPA (Focal Plane Array) / Flash LiDAR

Imagine it as a digital camera taking a picture. Once the LiDAR frames a shot, instead of taking a photo, “a single laser flashes and the scene is captured by an array of detectors.”

FPA LiDARs are perfect for drones because they’re cheaper, smaller, lighter, and more geometrically accurate than the LiDAR units we’re currently using—which means they offer the best of both worlds.

FPA LiDARs are also perfect for crash-avoidance systems in autonomous vehicles, which means demand for them is going to skyrocket in the next few years. As companies start producing FPA LiDAR at scale to meet demand, the cost of the sensors will fall. This means there will be a lot cheap sensors available for UAV use.

## Note

Less power is required in the sensors for the linear mode flash LiDAR, but the laser itself requires more power.

## Best LIDAR Sensors

Of the top 10 LIDAR sensors of 2016, the Velodyne LiDAR’s Puck LITE™, seems to be one of the best one in my personal opinion. It is one of the newer ones, with a low power consumption, yet still one of the most cost effective ones in the market; it is also lighter than most of the other LIDAR sensors, at 1.3 lbs. Click [here](https://youtu.be/Tw0EGdPVf8M?list=PLJS3hUrTgCtF7X0XmotIFWyKW4puaDmVY) for a brief video of the Puck LITE.

The other UAV lidar sensors are listed below:

**LeddarTech – Vu8 Lidar Sensor (0.17 lbs)\***

Mainly suited for navigation and collision avoidance for drones, trucks, construction vehicles, and public transportation vehicles.

This seems to be irrelevant because, we operate mainly on an open field, and preferably without interference.

**HDL-32E Lidar Sensor (4.4 lbs)**

Designed to exceed demands of the most challenging real world autonomous navigation.

With cabling, this sensor weighs 2.86 lbs, and with the height we are intending to fly, it may be better to consider lighter options (since ARGO itself already has quite some weight on it).

**Velodyne Puck VLP-16 Lidar Sensor (1.82 lbs)\***

Smallest, newest, and most advanced product in Velodyne's 3D lidar product range. More cost-effective, yet retains key features of Velodyne's breakthroughs.

**Velodyne LiDAR’s Puck LITE™ (1.3 lbs)\***

Lighter weight version of Velodyne Puck VLP-16 Lidar Sensor, there is no other difference, except it is 0.52 lbs lighter.

**Riegl – VUX-1UAV LiDAR Sensor (7.7 lbs)**

Provides the possibility to acquire data in dangerous and/or hard-to-reach areas.

Irrelevant to the needs of the laboratory and intended for professional UAVs.

**Routescene – UAV LidarPod (5.5 lbs)**

Developed specifically for UAVs use.

Weights 5.5 lbs.

**YellowScan Mapper Lidar Sensor (4.6 lbs)**

Gets true distance to vegetation and eliminates manned airborne or ground logistics.Aimed towards small areas (-100km linear), hard-to-access zones.

Mounted on MOST UAVs (double check); with battery up to 2 hours to autonomy

**YellowScan Surveyor UAV Lidar Sensor (3.5 lbs)**

Gets true distance to vegetation and eliminates manned airborne or ground logistics.Aimed towards small areas (-100km linear), hard-to-access zones.

Designed by surveyors for surveyors, fully autonomous and can be quickly mounted on any drone.

Mainly for civil engineering & mining professionals.

**Leica ALS80 Airborne Lidar Sensor (103 lbs)**

High performance airborne sensor for urban mapping.

It is 47 kg (103 lbs), intended for aircraft.

**Leica DragonEye Oblique Lidar Sensor (81.5 lbs)**

Industry leading 1 MHz airborne oblique lidar sensor

Again, intended for aircraft.

**Geo-MMS SAASM Lidar Sensor**

Flexible mounting and full integration with small unmanned vehicles, also includes an inertial navigation system. Indoor mapping capable (SLAM).

Applications doesn't really meet our needs (e.g. critical oil & gas infrastructure inspection).

**Geo-MMS Lidar Mobile Mapping System**

Similar to the one above.

After processed with Geodetic's lidar tool directly to the LAS format output, it is available with a wide range of sensors.

# Detailed Report

## What is LIDAR?

Lidar – **Light Detection and Ranging** or Lidar is a remote sensing technology where the environment is usually scanned with a pulsed laser beam and the reflection time of the signal from the object back to the detector is measured.

The Time-of-Flight (TOF) reflection time measurement can be used over distances from one meter up to several kilometers. To increase the range of lidar systems, very short laser pulses in the invisible Near Infrared range are used. These enable a far higher laser power compared to continuous wave lasers while still complying with eye safety requirements.

During the scanning process, the lidar system will gather individual distance points within an aggregate of points, from which 3D images of the environment can be computed. The laser scanners deflect the laser beam using deflecting mirrors, which enables them to achieve very wide fields of vision (FOV).

Most of the latest UAV lidar systems can rotate around their own axis and offer 360 degree visibility. Modern devices achieve very high data rates with over one million distance points per second.

## How LIDAR Works

Emission of a laser pulse

Record of the back scattered signal

Distance measurement (Time of flight x speed of light)

Retrieving plane position and altitude

Computation of precise echo position

## UAV Lidar Uses

**Lidar Sensors For Drone Collision Avoidance**

Within a lidar sensor, a number of independent elements are integrated into a single device and will generate critical ranging data for safe navigation along with precise positioning. Lidar technology has obstacle detection capabilities over a wide field of view making it a top performer as part of a sense and avoid solution. Lidar is the leading technology for automobile collision avoidance and also in driver-less cars.

Collision avoidance technology has now moved across into the consumer drone sector with the highly innovative DJI Phantom 4 (uses 2 Ultrasound sensors and 4 monocular sensors) and the Yuneec Typhoon H Pro (uses the Intel RealSense R200 3D camera) now with collision avoidance.

**Lidar Sensors For Ground And Above Ground Imagery**

The latest lidar sensors have integrated optical altimeter technology which deliver accurate distance measurements above ground level while meeting size, weight, and cost requirements of UAV manufacturers.

Agriculture and forestry use lidar to inspect vegetation such as leaves and crops. Also, the above ground imagery (for example forest canopy) can be removed to view the ground surface area.

**Lidar Drones For Structural Inspection**

The best lidar sensors have powerful built-in signal processing, large field of view, and multi-segment measurements which generate critical distance data and efficient obstacle detection which enable safe navigation when performing structural inspections.

**Lidar Sensors In The Night**

Lidar sensors also described as laser scanning will work in low contrast or shadowy situations, even at night.

**Lidar UAV Uses**

Agriculture & forestry

Archaeology and cultural heritage documentation

Corridor mapping: power line, railway track, and pipeline inspection

Topography in open-cast mining

Construction site monitoring

Building and structural inspections

Surveying of urban environments

Resource management

Collision avoidance

Shoreline and storm surge modeling

Hydrodynamic modeling

Digital Elevation Models

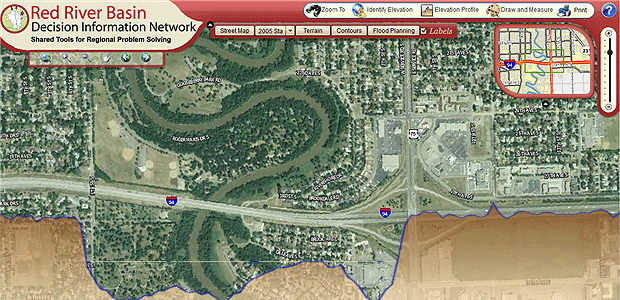
**Multispectral and Photogrammetry Imagery**

Lidar, multispectral and photogrammetry imagery are all very closely related technologies. In some sectors and situations, images from all 3 are required to give a full analysis of the terrain, vegetation or structure.

## Examples of Lidar Being Useful

(Aside from unmanned vehicles from Google and Tesla as well as the landing for SpaceX)

**Red River Basin and the Forests of Oregon (Major Flood of 1997)**



**Beneath the sea and in the fourth dimension**

The impacts of man and nature cause changes in topography, including underwater topography. So it's important to rescan periodically, to see how things have changed across the fourth dimension, time.

**LIDAR-equipped robots map a city’s interior.**

## How FPA (Focal Plane Array) / Flash LiDAR Works

Imagine it as a digital camera taking a picture. Once the LiDAR frames a shot, instead of taking a photo, “a single laser flashes and the scene is captured by an array of detectors.”

FPA LiDARs are perfect for drones because they’re cheaper, smaller, lighter, and more geometrically accurate than the LiDAR units we’re currently using—which means they offer the best of both worlds.

FPA LiDARs are also perfect for crash-avoidance systems in autonomous vehicles, which means demand for them is going to skyrocket in the next few years. As companies start producing FPA LiDAR at scale to meet demand, the cost of the sensors will fall. This means there will be a lot cheap sensors available for UAV use.

**Upside**

Today’s LiDAR systems essentially fire and process a single pulse at a time whereas the focal plane array systems will enable parallel processing.

FPA LiDAR rigs are light enough to mount on a small UAV (like a quadcopter) but still powerful enough to be useful. The low altitudes of these sensor deployments means that FPA LiDARs used for this purpose could have smaller collectors (lenses), lowering the overall mass of the system.”

**Downside**

Though less power is required in the sensors for the linear mode flash LiDAR, the laser itself requires more power “than in a conventional airborne scanning system, since thousands of detector sites must receive energy rather than the single collector site of a scanning system.”

Another problem is that flash systems in Geiger mode are very sensitive to noise like ambient light. So much so that “some experimental Geiger mode systems must be flown at night.” Furthermore, in Geiger mode, a flash LiDAR system is incapable of detecting the intensity of the return. “This means that the Geiger mode detectors provide range information only, not scene illumination.”

## LIDAR Data 50 Applications and Uses

**DEM (Elevation Value)**

1. DEM (Elevation Value): DEM stands for digital elevation model which has z coordinates value along with x and y. Elevation values are used everywhere, in roads, building, bridge and other. It has made easy to capture the surface height. Before LIDAR, ground survey or photogrammetry method was used to capture the z coordinates but the problem with this method was time consuming. LIDAR has made things easier and quicker.

**Micro-Topography\***

2. Micro-Topography: LIDAR is very accurate and precise technology which uses laser pulse to strike the object. Regular photogrammetry or other survey technology can miss the surface elevation value that is hidden by vegetation or forest canopy. But LIDAR can penetrate through the object and detect the surface value.

**Agriculture\***

3. Agriculture: LIDAR helps the farmer to find the area that uses costly fertilizer. LIDAR can be used to create elevation map of the farmland that can be converted to create slope and sunlight exposure area map. Both the layer information can be used to create high, medium and low crop production area. Extracted information will help farmer to save on the costly fertilizer.

**Forest**

4. Forest Planning and Management: LIDAR is widely used in the forest industry to plan and mange. It is used to measure vertical structure of forest canopy and also used to measure and understand canopy bulk density and canopy base height. Other uses of the LIDAR in the forest industry is the measurement of the peak height to estimate its root expansion.

**Forest Fire Management**

5. Forest Fire Management: LIDAR is becoming widely popular in forest fire management. Fire department is transforming from reactive to proactive fire management. LIDAR image helps to monitor the possible fire area which is called fuel mapping (fire behavior model). On this article author discuss, how British Colombia is using LIDAR information for the fire management.

**Precision Forestry**

6. Precision Forestry: Precision Forestry is define as planning and operating the site specific forest area to increase the productivity of wood quality, reduce cost and increase profits, and maintain the environment quality. LIDAR and aerial photo is used to perform precision forestry. Article on “Lidar Applications in Precision Forestry” talks in detail about its uses.

**Tourism**

7. Tourism and Parks Management: LIDAR DEM is used to plan the park and tourism area. High accurate land surface model helps to find the best area to have playground, trees and walking trail. Parks management is a big business and LIDAR technology is playing a vital role for its management.3D image of the park, generated from LIDAR technology helps for the future growth of the park.

**Environmental Assessment\***

8. Environmental Assessment: Micro topography data generated form the LIDAR data is used in the environment assessment. Environment assessment is done to protect the plants and environment. Remote sensing and surface information (LIDAR) is used to find the area that is affected by the human activities.

**Biodiversity for Birds\***

9. Biodiversity for Birds: As LIDAR technology is evolved in finding detail information about the forest. Forest are home for different type of birds, animals and insects. Scientist are using LIDAR data to analyze forest (vertical structure) to see whether it is suitable place for them. Vertical Structure of trees, shrubs and other plant tells, what species can live and prosper in that area.

**Flood Model**

10. Flood Model: LIDAR provides very accurate information. River is very sensitive and few meter of change in information can bring disastrous or loss of properties. So LIDAR is used to create high resolution and accurate surface model of the river. These extracted LIDAR information can be used for the 3D simulation for better planning of the structures or buildings on the river bank.

**Watershed and Stream Delineation**

11. Watershed and Stream Delineation: DEM generated from LIDAR is used to create watershed area and stream line delineation. High and accurate DEM is the major input to create this and GIS software is used to create it. This way you can calculate watershed for the particular water channels and find out stream channel for over land flooding.

**ELC**

12. ELC: ELC is short form of Ecological & Land Classification. It is done to provide the biological and physical information of the Landscape which helps in the sustainable management. ELC process helps in the range of sector like land use planning, environmental assessment, forest management, habitat management and many more. During the classification of Land, high resolution LIDAR data helps to understand the nature and type of the land, that will help in the ELC process.

**River Survey**

13. River Survey: Water penetration green light (532 nanometers) of the LIDAR is used to measure under water. Under water information is required to understand depth, flow strength, width of the river and more. For the river engineering, its cross section data is extracted from LIDAR data (DEM) to create a river model, which will create flood way and flood fringe map. In same way to understand sea under world, LIDAR data is used by the marine engineer.

**Modelling of the Pollution**

14. Modelling of the Pollution: LIDAR wavelength are shorter which operates in ultraviolet, visible region or near infrared. This helps to image the object which are in same size or larger than the wavelength. So LIDAR can detect pollutant particles of carbon dioxide, Sulphur dioxide and methane. This information helps researched to create pollutant density map of the area which can be used for better planning of the city.

**Mapping\***

15. Mapping: Surface model created from LIDAR is used to add graphical value to maps. DEM (from LIDAR) is added underneath of all layers that shows the 3D view of the land. Especially LIDAR data (DEM) is added on the aerial photography to show the 3D view which makes easier to plan roads, buildings, bridges and rivers.

**Management of Coastline**

16. Management of Coastline: LIDAR data of the coastline surface and under the water surface can be combined by researches to analyze the waves behavior and area covered by them. If these data are captured periodically then marine scientist can understand the coastline erosion occurrence.

**Transport Planning**

17. Transport Planning: LIDAR data for road helps engineer to understand it and give a roadmap for the building it. As LIDAR are highly accurate technology it helps to understand width, elevation and length of the existing road. Road engineer use LIDAR data for below things as well:

Calculate Cut & fill, culvert sizing, vegetation removal, grade calculations and more.

Height clearances

Right of way and surface conditions

**Oil and Gas Exploration**

18. Oil and Gas Exploration: As LIDAR wavelength are shorter, it can be used to detect molecules content in the atmosphere that has same or bigger wavelength. There is the new technology called DIAL (Differential Absorption LIDAR) which is used to trace amount of gases above the hydrocarbon region. This tracking helps to find the Oil and Gas deposits.

**Mining**

19. Mining: LIDAR is also used in the mining business in various task. It is used to measure the ore volume by taking series of photos of ore extraction space. These interval photos are used to calculate the volume.

**Archeology**

20. Archeology: LIDAR has played important part for the archeologist to understand the surface. As LIDAR can detect micro topography that is hidden by vegetation which helps archeologist to understand the surface. DEM created from LIDAR is feed into GIS system and it is combined with other layer for analysis and interpretation.

**Exploring Quarries and Minerals Area**

21. Exploring Quarries and Minerals Area: For Archaeology it is important to understand human civilization by finding the quarry and minerals site. So LIDAR is used to detect these spot.

**Viewshed Analysis**

22. Viewshed Analysis: Viewshed analysis is common name in GIS, it uses digital elevation model (DEM) to create viewshed map. It uses individual cell to determine that is visible or not from all other remaining cells. Accuracy of analysis depends on the inputted DEM. So high accurate DEM generated from LIDAR is used for these type of analysis.

**Solar Energy Planning**

23. Solar Energy Planning: Solar energy are getting popular for heating and electricity purpose. Solar panel are used to absorb the heat energy from the sun and it is converted to heat or electricity energy. For the installation of the Solar panel there are some basic requirements which are identified by the help of the LIDAR data. Like Solar panel should be kept to south facing of the roof and it should have minimum area and so on. To find out more about uses of LIDAR data in solar energy planning, read on page 12.

**Right to Light**

24. Right to Light: Every house owner has right for the light, other type of construction should not block the light for the individual. As LIDAR data can capture 3D model of the building, GIS analysis can be used to produce shadow map which shows illumination area during particular time of the day.

**Glacier Volume Changes**

25. Glacier Volume Changes: : LIDAR is used to calculate the glacier change over the period. LIDAR image are taken in time series to see the change happening. For example, LIDAR image was taken of Iceland from 2007-2009 and project was completed on 2012. These captured data will help scientist to know the amount of volume change.

**Gaming**

26. Gaming: LIDAR technology is used to capture the surrounding area and this data is feed into the computer and color code is added to it. For example for the race track game, LIDAR will be used to capture the view of the real race track. This captured race track data will be used for the game.

**Accident Scene**

27. Accident Scene: Ground based LIDAR can be used to capture the accident and crime scene. LIDAR technology can be used quickly to record the accident scene on the road that can be used later for the investigation. This allow the traffic to flow smoothly if there is the accident.

**Architecture**

28. Architecture: Ground based LIDAR technology can be used to capture the buildings structure. This digital information can be transfer to computer for architecture to design the house model.

**Recording of Building**

29. Recording of Building: Ground based LIDAR can be used to record the inside of the house. It can be used to record the interior design too. This extracted data can be printed on the 3D printer to model it. Or when building is rebuild this recorded information can be used to restore the interior design.

**BIM**

30. BIM: GIS is a valuable tool that helps in the planning, organizing and subsequent growth in the energy and utilities industries. The effective management of energy systems is a complex challenge. GIS has enormous potential for planning, design and maintenance of facility. Also it provide improved services and that too cost effectively.

**Cellular Network Planning**

31. Cellular Network Planning: LIDAR can survey the area with less time compared to other method. The collected surface model can be feed into the GIS system to create the line of sight or viewshed map. This outputted map can help cellular engineer to find proposed cellular antenna.

**Vehicle Automation**

32. Vehicle Automation: LIDAR is becoming more popular in vehicles to make it automatic. LIDAR is used to grab the information on the road and it is passed to computerized system to make a human being like decision. For example, LIDAR can detect the road yellow lines which tells the vehicle to stay within yellow lines. Nowadays vehicle uses Adaptive Cruise Control (ACC) which has LIDAR technology. It helps vehicle that is in cruise control to slow down when there is vehicle in the front and also speed up when there is no traffic.

**Sewer and Manhole Survey**

33. Sewer and Manhole Survey: There are some place in the sewer line where that is not accessible by human being physical. In this situation sensor attached with the robotic machine are sent into the pipe for survey. This information are later feed into computer for analysis.

**Meteorology**

34. Meteorology: LIDAR has been used for study of the cloud and its behavior since it was invented. It uses its wavelength to strike small particles in the cloud to understand it. There are different kinds of LIDAR presents which does typical task in the cloud.

Elastic backscatter LiDAR: It is the simplest type of LiDAR and is typically used for studies of aerosols and clouds.

Differential Absorption LiDAR (DIAL): It is used for the measurements of a gas like ozone, carbon dioxide, or water vapor.

Raman LiDAR: It is also used for measuring the concentration of atmospheric gases but also to take the quantity of aerosol parameters present.

Doppler LiDAR: It is used to measure wind speed.

**Geology\***

35. Geology: In geology the combination of LIDAR aircraft and GPS has evolved so much it is used finding the fault and measuring the uplift. The combination of above technology was used to find the Seattle fault in the Washington State, USA. NASA satellite called ICESAT that has LIDAR sensor is used to monitor glaciers and perform coastal change analysis.

**Astronomy**

36. Astronomy: In the exploration of MARS, LIDAR technology was used to create the topographic map of the red planet (the NASA Mars Global Surveyor). NASA\’s Phoenix Lander used LIDAR technology to the detect snow falling in the Mars atmosphere.

**Atmospheric Physics**

37. Atmospheric Physics: In the Atmospheric Physics, LIDAR is used to measure the concentration of oxygen, nitrogen, potassium, sodium and other gas particles in the middle and upper atmosphere. This information is used to create the density map.

**Oceanography**

38. Oceanography: LiDAR is used for calculation of phytoplankton fluorescence and biomass in the ocean surface. It is also used to measure the depth of the ocean (bathymetry). Typical example will be measuring of the coral Reef.

**Military**

39. Military: LIDAR has always been used by the military people to understand land. It creates high resolution map for the military purpose. They use LIDAR technology to understand the war place.

**COPS**

40. COPS: It is quite common technology in the law enforcement department. Police uses LIDAR gun to detect the speed of the vehicle and also to understand the traffic flow. This technology is so precise that they can pick up the targeted vehicle from the cluttered traffic.

**Forensic**

41. Forensic: 3D Laser scanning or LIDAR is becoming quite popular in forensic examination. Though the technology is new, it is embraced by police department, law enforcement agencies and government crime agencies.

**Imaging\***

42. Imaging: LIDAR technology is used to create 3D image of the object that is in distance. 3D imaging is done with both scanning and non-scanning systems. There is a technology which uses combination of fast gated camera and LIDAR to created 3D image (3D gated viewing laser radar). It is a non-scanning systems.

**Wind Farm**

43. Wind Farm: LIDAR is used in the wind farm to calculate the direction and strength of wind. LIDAR attached to the turbine helps to change the direction of the blade to generate more power.

**Dune Monitoring**

44. Dune Monitoring: : LIDAR is used to monitor the dune activities. It includes change in size and shape, vegetation, rate of change and other related dune activities.

**Urban Municipality**

45. Urban Municipality: LIDAR is used by urban municipality to survey the city. As LIDAR is accurate and quick to survey, it helps municipality to know where things are and what are the changes happened in the city. City assessment department can use LIDAR to find out what are things build up in the public backyard.

**Railway Infrastructure**

46. Railway Infrastructure: Traditionally railway track measurement was done by regular survey system. Now LIDAR can quickly perform the measurements of the railway track and the topographical and surrounding area of the railway path.

**Airport Infrastructure**

47. Airport Infrastructure: LIDAR is used to capture features in the airport like runway, terminal building, hangar and other objects. This allow airport authority to manage and operate airport system smoothly.

**Tunnel Surveying**

48. Tunnel Surveying: LIDAR is used to measure accurate and detailed measurements, used for analysis, assessment and modelling of the tunnel that is for railway track or road. This might be in the mountain, land or underwater.

**Tsunami Inundation Modeling**

49. Tsunami Inundation Modeling: Tsunami is a well-known natural disaster and can takes thousand lives and damage infrastructure. LIDAR technology help scientist to understand the area that will be covered when Tsunami happens. DEM produce by LIDAR gives the elevation value of the seashore and bathymetric data provides underwater elevation . These information, layered in the GIS will provide the inundate area when Tsunami occurs.

**Integrated Storm Water Management Plan**

50. ISMP: Integrated Storm Water Management Plan has become popular name compare to traditional system which is an ecosystem-based approach to rain water management. The goal of ISMP is to balance between: land use planning, storm water engineering, flood and erosion protection, and environmental protection. For the ISMP or traditional Storm water management system, elevation map is important. It is easy to produce contour from DEM which is created from the LIDAR data. LIDAR data are accurate and precise.

## LIDAR Sensors for UAVs

**LeddarTech – Vu8 Lidar Sensor**

The LeddarTech Vu8 is a compact solid-state lidar which provides highly accurate multi-target detection over eight independent segments. Detecting targets at up to a 215 meter range and weighting only 75 grams, the Vu8 delivers nearly twice the range for half the volume compared with the Leddar M16 from which it inspires.

The Vu8 uses a fixed laser light source, which significantly increases the sensor’s robustness and cost-efficiency. The Vu8 has a high tolerance to noise and interference. This means it is unaffected by other sensors’ signal, by lighting conditions including direct sunlight, and it provides reliable detection in various weather conditions including rain and snow.

The Vu8 sensor is particularly suited for navigation and collision avoidance applications in driver-assisted, semi-autonomous and autonomous vehicles, such as drones, trucks, heavy equipment for construction and mining, shuttles, buses and other public transportation vehicles.

Applications such as Advanced Traffic Management System (ATMS) requiring longer ranges as well as wide fields of view will also benefit greatly from the new Vu8 sensor.

**Features and Benefits of the Vu8 Lidar Sensor**

Detection range up to 215 m (≈ 700 ft)

Compact and lightweight (≈ 75 g)

8 independent segments with simultaneous acquisition and lateral discrimination capabilities

20°, 48° and 100° beam width options, for optimized field of view

Rapid refresh rate up to 100 Hz

Immune to ambient light

No moving parts, for ultimate robustness

Easy to integrate, includes Leddar Enabler SDK

Based on the modular LeddarVu platform for flexible integration and customization

Best cost/performance ratio

<https://youtu.be/-9Gbg5mjwm4>

**Velodyne – 3 Of the Best Lidar Sensors For UAVs**

Velodyne Lidar now provides a full line of sensors capable of delivering the most accurate real-time 3D data on the market. Their sensors are developed to create a full 360 degree field of vision environmental view for use in autonomous vehicles, industrial equipment, 3D mapping and surveillance. Velodyne have 3 lidar sensors for UAVs.

**HDL-32E Lidar Sensor**

The HDL-32E LiDAR sensor is small, lightweight, ruggedly built and features up to 32 lasers across a 40 degree vertical field of view. The HDL-32E measures only 5.7″ high x 3.4″ in diameter, weighs less than 2kg and was designed to exceed the demands of the most challenging real world autonomous navigation, 3D mobile mapping and other lidar applications.

Dual Returns

± 2 cm accuracy

1.3 kg with cabling (2.86 lbs)

32 Channels

80 – 100 meter range

700,000 Points per Second

360° Horizontal FOV

+10° to -30° Vertical FOV

Low Power Consumption

Rugged Design

Weighs less than 2 kg (4.4 lbs)

**Puck VLP-16 Lidar Sensor**

Velodyne’s new PUCK™ VLP-16 lidar sensor is the smallest, newest, and most advanced product in Velodyne’s 3D lidar product range. It is more cost-effective than similarly priced sensors and developed with mass production in mind. It retains the key features of Velodyne’s breakthroughs in lidar: Real-time, 360 degree horizontal FOV, 3D distance and calibrated reflectivity measurements.

Dual Returns

830 grams

16 channels

100 meter range

300,000 points per second

360 degree Horizontal FOV

± 15° vertical FOV

Low Power Consumption

Protective Design

Weight of 830 grams (1.82 lbs)

**Velodyne Puck Lite Lidar Sensor For UAVs**

Velodyne Puck VLP-16 Hi-Res Lidar Sensor For UASVelodyne LiDAR’s Puck LITE™ is a lighter weight version of the VLP-16 PUCK for applications that demand a lower weight to meet their requirements. The Puck LITE™ has identical performance to VLP-16 with the only difference in weight of 590 grams (1.3 lbs) versus 830 grams for the VLP-16.

No other changes have been made to the Puck LITE™ as it retains its patented 360 degree surround view to capture real-time 3D lidar data which includes distance and calibrated reflectivity measurements.

Here is a terrific video which explains how lidar is being used and what the Velodyne lidar sensors can do.

<https://youtu.be/Tw0EGdPVf8M?list=PLJS3hUrTgCtF7X0XmotIFWyKW4puaDmVY>

**Riegl – VUX-1UAV LiDAR Sensor**

Laser scanning utilizing high-end unmanned airborne platforms provides the possibility to acquire data in dangerous and/or hard-to-reach areas, while offering an excellent cost-to-benefit-ratio for numerous applications, e.g., precision farming, forestry, and mining.

For years, Riegl Airborne Laser Scanners have been successfully used in powerful unmanned airborne platforms. With the VUX-1UAV airborne scanner and the RiCOPTER which is Riegls‘s remotely piloted aircraft system for Unmanned Laser Scanning (ULS), Riegl have revolutionized the commercial and civil market with its advanced systems.

The Riegl VUX-1UAV (former VUX-1) is a very lightweight and compact lidar laser scanner, meeting the challenges of emerging survey solutions by UAS/UAV/RPAS, both in measurement performance as in system integration. With regard to the specific restrictions and flight characteristics of UAS, the Riegl VUX-1UAV is designed to be mounted in any orientation and even under limited weight and space conditions.

It is modest in power consumption with the instrument requiring only 1 power supply. The entire data set of an acquisition campaign is stored onto an internal 240 Gigabyte SSD and/or provided as real-time line scan data via the integrated LAN TCP / IP interface.

**VUX-1UAV Lidar Sensor Main Features:**

10 mm survey grade accuracy

Scan speed up to 200 scans per second

Measurement rate up to 500,000 measurements per second

(@ 550 kHz PRR & 330° FOV)

Operating flight altitude up to more than 1,000 feet

Field of view up to 330 degree for practically unrestricted data acquisition

Regular point pattern, perfectly parallel scan lines

Cutting edge Riegl technology providing

– echo signal digitization

– online waveform processing

– multiple-time-around processing

Multiple target capability – practically unlimited number of targets echoes

Compact (227 x 180 x 125 mm), lightweight (3.5 kg) and rugged

Easily mountable on professional UAS / UAV / RPAS

Mechanical and electrical interface for IMU mounting

Electrical interfaces for GPS data string and Sync Pulse (1 PPS)

LAN-TCP/IP Interface

Scan data storage on internal 240 Gigabyte SSD Memory

**VUX-1UAV Lidar Sensor Main Applications**

Agriculture & forestry

Archaeology and cultural heritage documentation

Corridor Mapping: power line, railway track and pipeline inspection

Topography in Open-Cast Mining

Construction-site monitoring

Surveying of urban environments

Resource management

**Routescene – UAV LidarPod**

Routescene LidarPod With Velodyne Sensor For DronesThe Routescene UAV LidarPod is a complete turnkey system developed specifically for use on UAVs. This company worked with the surveying industry and it’s their expertise which is behind the Routescene UAV LidarPod.

Routescene designed a reliable, practical and cost-effective solution for lidar applications. The UAV LidarPod is a robustly engineered and self contained system. It is simple to operate and enables rapid deployment in the field. The turnkey solution includes LidarViewer which is the specialized software to handle the resulting data.

The LidarPod sensor combines the best technology on the market to capture survey grade positional accuracy together with a very high point cloud density.

**Points Per Second**

The Routescene LidarPod will collect 700,000 points per second, which at an altitude of 40 meters (131 feet) and flying speed of 30 km per hour (18.64 mph) equates to 300 points per square meter. This offers a fantastic richness in the dataset which greatly enhances the detail which can be collected.

**LidarPod Is Very Light**

The Routescene UAV LidarPod total weight is less than 2.5 kg (5.5 lbs). This low weight will enable a 20 minute flight duration, the typical time required to perform a survey, allowing coverage of 1 square km on a single set of batteries.

**Quality And Level Of Resilience**

The Routescene UAV LidarPod contains all you need to collect precise survey data, quality control the data in real-time and create a very dense and accurate georeferenced point cloud. This means everything you need is built into the system including the lidar sensor, GPS / INS, radio telemetry, data storage and power management. No external components are necessary which eliminates the possibility of integration issues and loose connectors.

The internal firmware controls the sensors, parses the raw data and transmits data samples to the Routescene Ground Station; it also manages and monitors power consumption of the LidarPod.

The LidarPod uses the Velodyne HDL-32e lidar sensor mentioned above which delivers unsurpassed image resolution. Highlights of the Velodyne HDL-32e within the LidarPod;

32 laser sensors / detector pairs

Class 1 eye safe

905 nm wavelength

Time of flight distance measurement with intensity

700,000 3D points per second

Maximum Range: 100 meters with range accuracy of < 20 mm

Field of View: 360 degree vertical and 41 degree horizontal

Angular resolution (vertical): 1.33 degrees

Shock: 500 m/sec2 amplitude, 11 msec duration

Environmental Protection: IP67

**Processing Lidar Data**

Routescene have developed specialized software called LidarViewer, which enables you to easily import, visualize, and apply filters to the large volume of data you collect in a smart way, enabling the use of GIS and CAD packages thereafter.

**LidarPod GPS \ INS**

A state of the art integrated Real-Time Kinematic (RTK) GPS and Inertial Navigation System (INS) provides accurate position, velocity, acceleration and orientation under the most demanding conditions. The dual antenna moving baseline Real Time Kinetmatic (RTK) GNSS solution ensures that the LidarPod can achieve the highest accuracy possible for the lowest weight.

The GPS\INS sensor combines temperature calibrated accelerometers, gyroscopes, magnetometers and a pressure sensor with a multi channel RTK GNSS receiver. These are coupled in a sophisticated fusion algorithm to deliver accurate and reliable navigation and orientation.

Triple-frequency GNSS receiver that provides up to 1 cm accuracy positioning and supports all of the current and future satellite navigation systems, including GPS, GLONASS, GALILEO (European Satellite Navigation System) and BeiDou (Chines Satellite Navigation System). It also supports the Omnistar service for hassle free high accuracy positioning.

**UAV Mounting Kit (optional)**

A specially designed and tested solution for mounting the LidarPod and 2 GPS antennas onto your rotary UAV. The mounting kit includes an equipment plate which is compatible with 12 mm diameter UAV equipment rails, the 2 rails being 160 mm apart. The equipment plate includes quick release clamps for easy deployment.

<https://youtu.be/1AJVvCFlKmQ>

**YellowScan – 2 UAV Lidar Sensors**

YellowScan designs and develops ultra compact and lightweight lidar 3D laser mapping and aerial remote sensing solutions for drone deployment in industrial & scientific applications.

Benefit of YellowScan UAV Lidar Sensors

Scanning Vegetation & Crops: YellowScan’s technology is one of the few to get true distance to vegetation in near real-time. Scan fast growing vegetation and crops as frequently as needed.

Optimized Maintenance Operations: Quick, light and easy to mobilize, the whole system (UAV+Lidar) can be carried in car trunk or airplane luggage: ideal for quickly surveying limited sections of the network which has not or can’t been scanned with large airborne lidar (sections missed, hard-to-access areas, fast growing vegetation sections)

Security: YellowScan UAV mapping allows for quick and complete acquisition while eliminating manned airborne or on the ground logistics.

The Yellow Scan Lidar Solutions are aimed towards;

Small areas (less than 10 square km or 100km linear)

Need to penetrate vegetation

Hard-to-access zones

Data needed in near real-time / frequently / regularly

Accuracy range of 5-50 cm

**YellowScan Mapper Lidar Sensor**

The YellowScan Mapper lidar sensor is a lightweight turn key surveying solution for drones and other ultra-light aircraft. It’s small size and ultra-light weight allow it to be mounted on most UAVs.

**Yellow Scan Mapper Applications**

Corridor mapping

Environment works

Archaeology

Forestry

**Yellow Scan Mapper Lidar Sensor Benefits**

Tested and operated by professionals world wide in various scenarios

Robust and reliable

Turn-key and simple to operate

Open architecture with interoperable software: fits many applications from research to industrial mapping

Fully autonomous and can be mounted quickly on any drone

**Yellow Scan Mapper Specifications**

Precision: 10 cm

Absolute accuracy: 15 cm

Laser scanner frequency: 40 kHz

Weight: 2.1 kg battery included

Power consumption: 10W

Autonomy: 2 hours typical

Size (mm): L172 x W206 x H147

**YellowScan Mapper Lidar System Includes**

High-end Attitude and Heading Reference System (AHRS) allowing precision measurement of the attitude

Dual-frequency GNSS receiver, capable of operating in RTK or PPK positioning mode

Multi-echo laser scanner

On-board computer for continuous data acquisition and processing

Battery (up to 2 hours of autonomy)

Worldwide technical and operational support

**YellowScan Surveyor UAV Lidar Sensor**

YellowScan Surveyor Lidar Sensor For DronesThe YellowScan Surveyor is one of the lightest and most accurate lidar sensor solutions for Civil Engineering & Mining professionals. This YellowScan Lidar UAV surveying solution has the highest level of accuracy and density which is also capable of producing real-time georeferenced point cloud data.

YellowScan Surveyor is a fully integrated system designed for the most demanding of terrains. The YellowScan Surveyor is quick and easily adapted to any drone.

Now, the YellowScan Surveyor does not replace the YellowScan Mapper mentioned above, but complements the YellowScan Mapper with a solution ideally suited for precise topography and demanding requirements for civil engineering and mining applications.

**Yellow Scan Mapper Lidar Benefits**

Designed by surveyors for surveyors

Robust and reliable

Turnkey, quick and simple to operate

Fully autonomous and can be quickly mounted on any drone

Subscale decimetric accuracy for highest density level data in demanding survey applications

**YellowScan Mapper Lidar Specifications**

Precision: 4cm

Absolute accuracy: 5cm

Laser scanner frequency: 300 kHz

Weight: 1.6 kg (3.5 lbs) battery included

Power consumption: 15W

Autonomy: 2 hours typical

Size (mm): 100 x 150 x 140

<https://youtu.be/2OMiQJHt4Zw>

**Leica Geosystems Lidar Sensors**

Leica Geosystems are renowned for the Imaging and Lidar sensors. Their Lidar systems offer high accuracy due to their best-in-class performance in pulse and scan rate.

While they have multispectral and imaging sensors which are mounted on UAVs, their Airborne lidar sensors are large and heavy. Leica have 2 airborne lidar sensors which are too heavy for small UAVs. Their large and heavy lidar sensors for manned aircraft are as follows;

Leica ALS80 Airborne Lidar Sensor: It’s a high performance airborne sensor for urban mapping and utility corridor surveys. The weight of the ALS80 is 47kg (103 lbs) so it really is an aircraft lidar sensor.

Leica DragonEye Oblique Lidar Sensor: Industry leading 1 MHz airborne oblique lidar sensor. The weight of the DragonEye lidar sensor head is 37 kg (81.5 lbs). Again, this is also a lidar sensor for aircraft.

I would expect Leica to start designing small UAV lidar sensors in the near future. They have all the technology and this market is growing massively.

**Geodetics – 2 Lidar Sensors For UAS**

Geodetics Geo-MMS SAASM Lidar Sensor For UASGeodetics was founded in 1999 by a team of scientists with the goal of providing precise positioning technologies in the civilian market. Since that time, Geodetics has grown into a product and integrated solution provider for Positioning, Navigation and Timing systems for a wide range of civilian and defense applications.

Their products and systems have been deployed in mission critical applications including Aerial Refueling, Aerial Combat Training, Intelligence, Surveillance and Reconnaissance, UAV’s, Aerostats and Dismounted Soldier tracking.

**Geo-MMS SAASM Lidar Sensor**

The Geodetics Geo-MMS SAASM is a fully integrated lidar mapping payload for integration with small unmanned vehicles. The Geo-MMS system includes an inertial navigation system, utilizing a SAASM GPS sensor with a path to M-Code, coupled with a lidar sensor. Raw data from the integrated GPS, IMU and lidar sensors are recorded on the internal data recording device and can be post-processed using Geodetics’ lidar tool software package to directly geo-reference the lidar point clouds.

**Geo-MMS SAASM Specifications**

Flexible mounting for different platforms including UAV, UAS, ground vehicles and robots

Minimized sensor size and weight to meet payload restrictions (5 lbs minimum payload)

Available with a many IMU’s to support a wide range of application requirement

Centimeter-level position accuracy (dual-frequency RTK configuration)

On-board data logging of all sensor and navigation solution data

User interface to fully control individual and collective GPS, IMU, Laser setting

Full post-processing support for GPS/IMU/LiDAR with RTD-Post and CYO

LAS file output

**Geo-MMS SAASM Lidar Applications**

Intelligence, Surveillance and Reconnaissance (ISR)

Situational Awareness

Sense and avoid

Asset management

Coastal surveillance

Hydrometric mapping

Critical Oil & Gas infrastructure inspection

DEM/DSM generation

Indoor mapping capable (SLAM)

**Geo-MMS Lidar Mobile Mapping System**

The Geodetics Geo-MMS is a fully integrated lidar mapping payload for integration with small unmanned vehicles. The Geo-MMS includes an inertial navigation system coupled with a lidar sensor. Raw data from the integrated GPS, IMU and lidar sensors are recorded on the internal data recording device.

They can then be post-processed using Geodetics’ lidar tool software package to directly geo-reference the Lidar point clouds with LAS format output. Geo-MMS is available with a wide range of sensors.

**Geo-MMS Specifications**

Flexible mounting for different platforms including UAV, UAS, ground vehicles and robots

Minimized sensor size and weight to meet payload restrictions (5 lbs minimum payload)

Available with a many IMU’s to support a wide range of application requirement

Centimeter-level position accuracy (dual-frequency RTK configuration)

On-board data logging of all raw and navigation solution data

User interface to fully control individual and collective GPS, IMU, Laser setting

Full post-processing support with GPS/IMU Geo-PostProcessing

LAS file output

**Geo-MMS Lidar Applications**

Intelligence, Surveillance and Reconnaissance (ISR)

Situational Awareness

Sense and avoid

Asset management

Coastal surveillance

Hydrometric mapping

Critical Oil & Gas infrastructure inspection

DEM/DSM generation

Indoor mapping capable (SLAM)

<https://youtu.be/QvvQr7xgj3s>

## How LIDAR is Revolutionizing Maps, Geospatial Data

It's faster than a speeding bullet. It can measure buildings in a single pulse. It can scan the ocean floor and peer through forest canopies to measure undergrowth. It's LIDAR – light detection and ranging.

A standard LIDAR system emits a beam of light from a laser source and then captures the returned light in sensors as it bounces back from a reflecting object, measuring the distance by calculating the time required for the round trip. While LIDAR systems were used by the federal government as early as the 1960s — primarily for atmospheric studies — it wasn't until after 2000 that a combination of factors resulted in a boom of LIDAR data-gathering projects that are now bearing fruit at federal, state and local government levels.

U.S. troops have used LIDAR to map the difficult terrain in Afghanistan and a Colorado State University scientist used it in creating the first forest height map to measure carbon cycles in ecosystems.

"It's being used by just about everybody who uses a map," said John English, LIDAR data coordinator for Oregon's Department of Geology. "Every municipality and county is using it. The Department of Land Management and the U.S. Forest Service use it for their forest inventory surveys."

According to English, the agencies are increasingly turning to LIDAR because the technology has gotten both less expensive and more accurate, and, because surveys are generally done from aircraft, vast amounts of territory can be covered quickly. "It's been a huge timesaver," he said. "The estimate of savings is incalculable."

Kirk Waters, a program manager at the National Oceanic and Atmospheric Administration's Coastal Services Center, agrees. "LIDAR is a way to get fairly accurate elevations over a broad area at a reasonable price," he said.

Waters pointed to a March 2012 report by the U.S. Geological Survey that found that a national program of collecting LIDAR data would result in net benefits of between $116 million and $620 million a year. According to the study — the National Enhanced Elevation Assessment — the biggest savings are to be realized in flood risk management, infrastructure and construction management, natural resources conservation, agriculture and water supply management.

Elevation data can tell city planners where to plan mitigation for floods. It can tell farmers where to expect irrigation runoff and where to plant crops that require the most expensive fertilizers. Cities are using LIDAR to build 3D maps.

In all, "the study came up with 600 different uses,” Waters said. “There's just tons of applications."

"It's at the beginning stages," said Steve Snow, a mapping and LIDAR specialist with geospatial tech company Esri. "Everybody is learning about the technology." Esri, in fact, just added the ability to import native LIDAR directly into its industry-standard ArcGIS software.

In principle, the technology behind LIDAR is simple. By measuring the time it takes light to bounce off an object, and knowing the speed of light (186,000 miles per second), one can detect the distance of the object. The challenge has been in developing equipment that can fire rapid pulses of light — in some cases up to 150,000 pulses per second — and that can measure the returning light with accuracy.

LIDAR systems vary in the wavelengths of light and the power of the pulses employed. High-energy pulse systems, for example, typically are used for atmospheric research, while lower-powered micropulse systems are more often employed for downward scanning, since they are considered "eye safe."

And although most airborne LIDAR systems use 1064-nanometer laser beams, bathymetric LIDAR systems — those used to penetrate water — employ a narrower 532-nm beam. Bathymetric LIDAR also transmits two light waves, one infrared and the other green. As a result, it can detect two returning signals, one off the water surface and the other from the seabed.

Other critical elements in the development of LIDAR systems have been the enhancements in the production of higher-resolution and more flexible scanners, optics and photoreceptors.

Finally, collecting LIDAR data from aircraft involves a few additional challenges. Because the LIDAR sensor is moving, the changes in location between the firing of the pulse of light and its return must be accounted for in making any measurement. That required the development of fast, high-resolution GPS devices and inertial measurement units that measure velocity and orientation.

Coordinating of this, of course, is no mean feat, nor is digesting the massive amounts of data that are produced.

According to Waters, NOAA's LIDAR scans are shooting between 100,000 and 200,000 points per second with about up to 10cm of error. "The rest is math," Waters said. "Lots of math, but it's still just math."