# Processing of Airborne Laser Data and Images

***-- Versatile products through skilled processing***

*The workflow for processing airborne laser data (LiDAR) and airborne images may be divided into six major steps: Initial setup, Calibrating data, Classifying points, Processing images, Validating positioning and Creating delivery products. The accuracy requirements and the nature of the delivery products determine what detail steps need to be carried out. Proper flight planning and careful field measurements lay a foundation for successful data processing and delivery.*

## Initial setup

The initial setup involves importing all the necessary raw data into the processing software, applying coordinate transformations, organizing the data, throwing out unnecessary information and checking that the project area has been covered.

The number of points in a laser survey project may be anything in the range from 5 million to 50 billion. A large data set needs to be divided into smaller, more manageable geographical blocks. About 5-20 million points is suitable block size which will fit in random access memory and still leave room for information that various processing routines need to build internally.

Many of the processing steps can be executed as batch processes without human supervision. Distributing the computation to several computers on the network can speed up these automatic tasks..

No matter how sophisticated the automatic routines are, the human operator always has to do visual checking of the results and fix problem locations interactively. The ability to view the results of each step in a fully 3D environment is the key to producing accurate models. Laser data needs to be viewed in top views, cross section views and in views with freely selected 3D-rotation using different coloring modes: color by class, intensity value, elevation or flight pass.

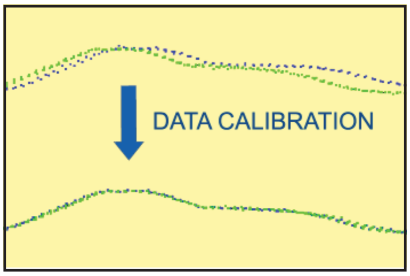
To ensure proper classification, the operator needs to be able to see the laser data overlaid with orthophotos or individual airborne images.

## Calibrating data

All laser scanner owners calibrate their instrument but this is not enough to achieve accurate positioning. The calibration parameters need to checked for each flight session. In a sense, the laser scanner owners are constantly fine tuning the calibration of the sensor.

Calibration is based on comparing the laser data produced by different flight passes which overlap each other (picture 1). To make this task possible, each project flight session must include some flight passes which overlap other flight passes. To increase the amount of comparison area, one normally flies some crossing flight passes for calibration purposes.

Aerial sites will have side overlap between parallel flight passes automatically. Corridor sites are more demanding when it comes to mission planning to ensure that the data can be internally checked and calibrated. It is not enough to fly a corridor object in one direction only. One should add crossing flight passes at regular intervals (5 – 20 km).




*Picture 1. TerraMatch measures the mismatch between overlapping strips and adjust them.*

The calibration is normally based on surface to surface matching of the different flight passes. As preparation step, one has to classify ground in each flight passes separately to remove the noise that vegetation would bring into the comparison. This classification can often be done as an automatic batch process.

The most common, basic matching steps are:

1. Solve misalignment angles between laser scanner and IMU together with scanner mirror scale. This step can be done using only some selected blocks from the project.

2. Solve dZ correction for all flight lines. It is very common that some flight passes are a few centimeters too high and some a few centimeters too low.

Only when the matching of flight passes is complete, should one continue with rest of the processing steps.

## Classifying points

Classifying points is a task where we try to determine what type of object each laser point is a reflection from. This task is often the step which consumes the most operator time. Even though automatic routines will do over 90% of the work, this will still leave millions of points where the human operator has to make classification decisions.

The survey flight will often produce data which is not needed in the final product. The operator will want to classify these points out of the active data set. Points may be excluded because they are:

- *outside the project area*
- *from the overlap area where points from another flight pass will be kept*
- *lower positional quality due to weather conditions or some other reason*

The level of classification detail varies greatly from one project to another. In many projects, the only delivery product is a ground model and perhaps contour drawings generated from the model. In those cases, 5-8 classes is all that is needed (table 1).

*Low vegation*, *Medium vegetation* and *High vegetation* classes will not mean that the object is necessarily vegetation. Points in these classes will include hits on other surface objects as well: cars, trains, lampposts, wires etc.

Some engineering type projects may have more than 50 classes into which points need to be classified. The more detailed the classification, the more operator time is required.

Usually classification is based on first running automatic routines and then performing interactive editing of the results. The interactive editing is a step where the user needs to be able to view the data set in flexible ways and to view other information sources at the same: orthophotos, existing vector maps, old surface models etc.

Orthophotos are particularly important to ensure proper handling of the laser data. Images are essential to understanding what the laser scanner has captured.

*Table 1. Typical definition of laser point classes*

| Nr. | Class | Description |
|---|---|---|
| 1 | Default | not classified yet |
| 2 | Ground | Ground |
| 3 | Low vegetation | Objects < 0.3 m above ground |
| 4 | Medium vegetation | Objects 0.3 – 2.0 m above ground |
| 5 | High vegetation | Objects > 2.0 m above ground |
| 6 | Building | Building roof |
| 7 | Low point | Bad points |
| 8 | Model-key-point | Key points for ground model |
| 9 | Overlap | Points excluded from processing |

# Processing images

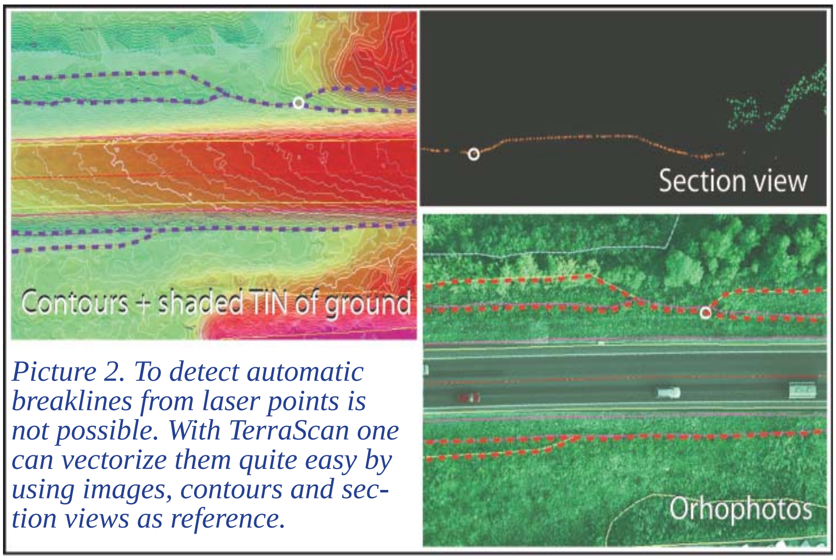
Images and laser data belong to the same integrated processing environment. One must have a ground model to produce orthophotos but at the same time the laser data operator needs to have an orthophoto to produce the ground model in the first place!

Laser data and images captured during the same flight form the optimal combination. In this case the two data sources have captured the same reality and are based on the same positioning solution.

The key advantages from integrated laser and image processing are:

- *Images support classification decision*
- *One can extract color values from images to laser points*
- *One can vectorize features on the orthophoto and derive elevations from laser data (picture 2).*
- *One can vectorize 3D objects (buildings, powerline towers,...) in perspective views*
- *Easy to ensure that the two data sets have the same positioning*
- *Easier to learn and use than if the processing takes place in different systems*

Nowadays camera systems are normally flown with aircrafts equipped with good GPS/IMU systems. This provides very accurate raw positioning information for the airborne images. When combined with an automatic ground model from laser data, the raw images can be turned into a rough orthophoto with very little effort. This rough ortho can be used as a background raster when performing interactive editing of the laser data ground classification.




*Picture 2. To detect automatic breaklines from laser points is not possible. With TerraScan one can vectorize them quite easy by using images, contours and section views as reference.*

Final orthophotos will usually require collection of tie points between images and that an aerial triangulation process is run to ensure the best possible positioning. The final orthomosaic will require color balancing between raw images and seamline editing.

Orthophoto production normally requires significantly less operator time than laser data processing of the same area.

# Validating positioning

The positioning of the data sets need to be validated before building any delivery products. Both xy positioning and elevation accuracy need to checked against field measurements.

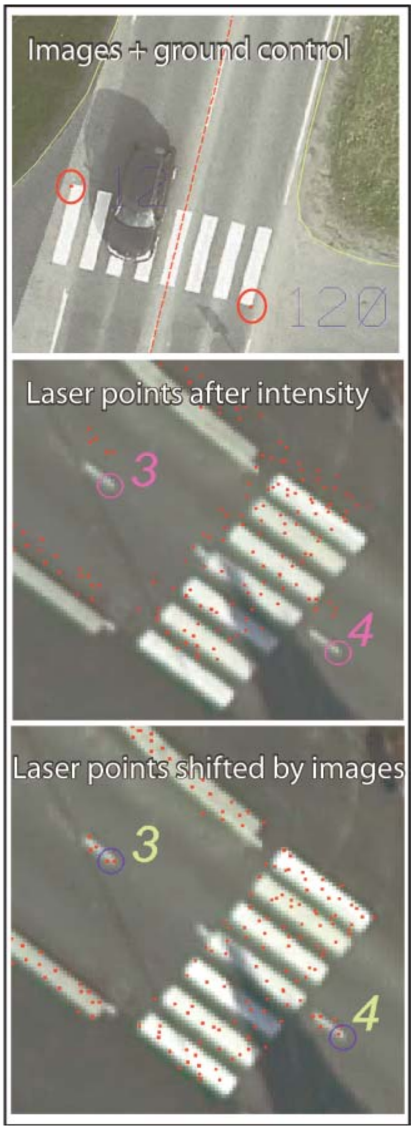
Elevation accuracy of the laser data is very easy to check. This can be normally done as one automatic routine which reports the standard deviation of the laser ground model and reports if the laser data is systematically too high or too low. In a typical case, one ends up apply a systematic correction raising or lowering the laser data a few centimeters.

Xy positioning of the laser data is harder to check. One method for this is using field measurements on paint markings on asphalt. Reflective, bright paint markings will show up as high intensity linear features in the laser data and these can be matched to field measurements (picture 3).

# Creating delivery products

The delivery products from laser data vary greatly from one project to another. In the worst case, laser data is translated into ground grid models only or ground contour drawings both of which will lose majority of the information captured.

Laser data captures very accurate information about the ground and this is modeled best as a triangulated surface model (TIN). To create a TIN model from laser data, it is usually not practical to use all




*Picture 3. Ground control points with orthophotos let you control the position of images and laser points and shift them to right xy-position.*

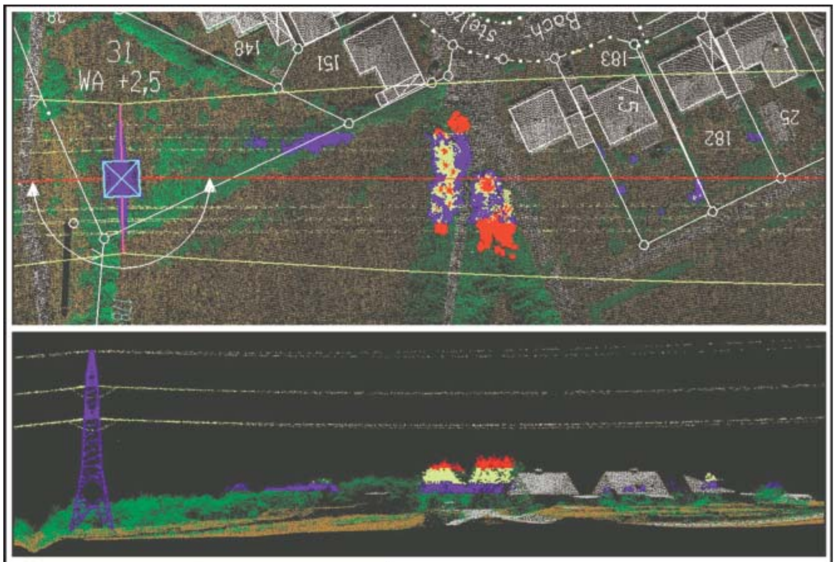
ground points. Common practise is to classify 'model-key-points' or relevant points from the millions of ground points. This often results in 90% – 95% reduction in data volume.

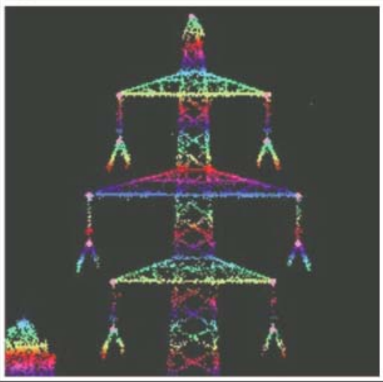
In addition to the ground, laser data carries a lot of information about objects above the ground. Practically all uses of ground models also require some information about the objects above the ground.

A more complete data delivery would include at least some of the following:

- *A*ll classified laser points
- Ground TIN models based
- 3D building vector models
- 3D breakline vectors
- 3D tree cells
- True-orthophotos

These more detailed products will naturally require more operator effort to produce.



Distances from wires to objects:
< 5 m
< 7 m
< 10 m

*To detect wires and details of towers from power line data and then to analyze the results requires usual skilled operators and a lot of time (images by Nebel &Partner).*