

Basemaps for Orienteering

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All orienteering maps start with a basemap. A basemap is the piece of paper upon which a mapper adds all the additional features in the terrain that he or she finds while performing the "fieldchecking." It forms a framework upon which all the other features can be placed relative to each other and to the earth's surface. In almost all cases, the basemap has the contours and a rectilinear grid drawn on it at a particular scale. Basemaps are derived from 4 main sources:

- 1) A blank piece of paper (called a "white paper map")
- 2) An existing map, such as a USGS topo or old orienteering map
- 3) An aerial photo survey
- 4) A lidar survey

A blank paper basemap is just that: starting from a completely blank piece of paper. This is extremely difficult, and rarely done. Using an existing map can be a good choice if the contour data was of good quality to begin with and is still mostly up-to-date. USGS topo maps do not have a high level of detail and the detail that is there is often incorrect, but they are often used due to a lack of anything better. I don't recommend this. Aerial photo surveys have been the method of choice for making basemaps over the years, and they are still used widely today. This involves taking a set of overlapping stereophotos of the area from an aircraft, and then sending those photos to a manual stereoplotter (a person who uses a machine called a "stereoplotter" to draw the contours by hand. This can also be done by computer these days. The stereoplotter will also add any other useful information that can be seen on the photos such as roads, clearings, large cliffs and boulders. These linear and point features are very useful to the fieldchecker as reference points.

The Lidar Basemap

A new technology has come along in the last ten years or so which has made the production of basemaps easier and in many cases, more accurate than even the stereophoto method. It is called Lidar, which stands for **L**ight **D**irection **A**nd **R**ange. Its exactly the same as radar, but uses optical light as the medium instead of radio waves. You may have heard of the police using lidar instead of radar to catch speeders on the highway. The principle is exactly the same. A pulse of light is aimed at a target and the time it takes for that pulse to bounce off the target and return is measured (Fig 1). Multiplying this time by the speed of light gives the distance to the target (or rather twice the distance, since its an out-and-back trip).

The laser is mounted underneath an airplane and a mirror is attached which scans the laser beam from side to side as the plane flies over the ground (Fig 2). The laser is pulsed hundreds of times per second as the mirror scans back and forth, so that each sweep of the mirror measures the distance from the plane to all those points along a line.

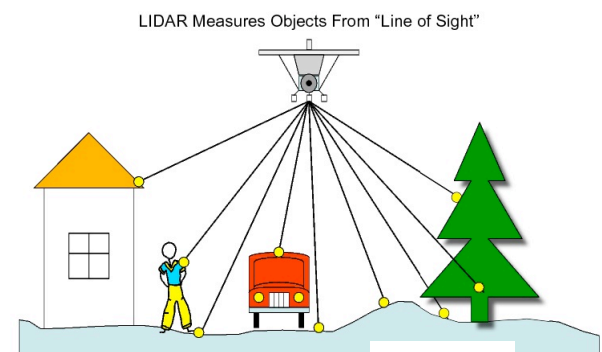


Figure 1.

BAE SYSTEMS

PAMAP

PHOTO SCIENCE

Lidar Basics

- Mirror sweeps laser beam across the ground.
- Range to target is determined by measuring time interval between transmission and return of reflected laser pulse.
- Aircraft position is determined using GPS phase differencing techniques.
- Pointing direction of laser determined with Inertial Measuring Unit (IMU) and recording of mirror position.
- Data streams recorded and synchronized for post processing.

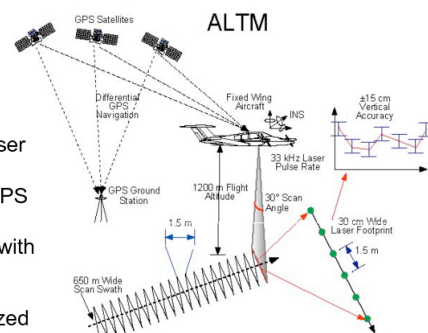


Figure 2.

As the plane moves forward a successive line is measured a short distance ahead of the previous, so as the plane moves across the ground it measures the distance to all the points in a swath beneath it. Using GPS and gyroscopes to measure the location of the plane and correct for small wobbles (turbulence and steering, etc), the exact direction that the laser was pointing for each pulse can be determined.

The end result is a large set of x,y,z points representing the entire surface that the plane flew over. Laser pulses bounce off of whatever surface

they hit. That surface might be bare ground if its an open field or highway, or the roof of a building, or the forest floor if the pulse happens to fall into a gap between the branches. It might also be the tops of trees in a heavily forested area. However, even if a pulse does hit a leaf or tree branch, some of the light might get through to reach the ground (Fig 3). In this case, you will get *two* (or more) returned pulses from a single sent pulse. The first one being a branch or tree top, and the second being from a lower branch, an understory shrub or the ground under the trees.

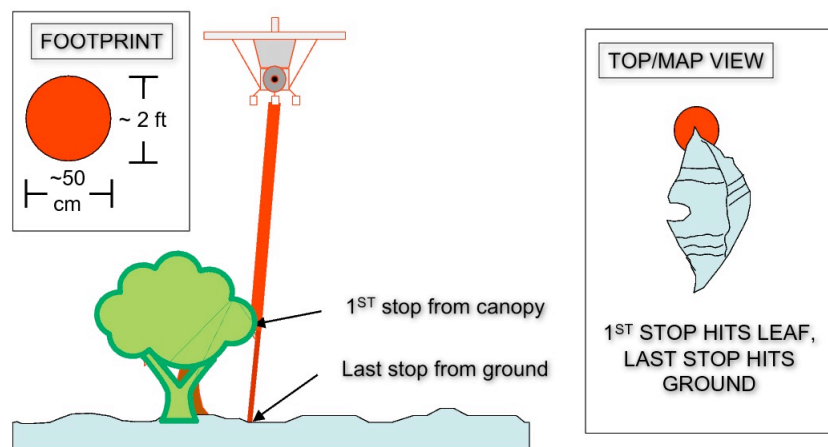


Figure 3.

Getting Down to Earth

Figure 4 shows a three-dimensional rendering of the lidar data collected near PNC park in Pittsburgh. You can easily see the details of the stadium seats, nearby buildings and even trees in the surrounding parking lots. Filtering software is used to try to separate the hard, bare earth returns from all of the vegetation etc. It is these "bare-earth" returns that are used to make the final basemap. The software program is used for that. In addition to the positional information, the intensity of the pulse reflection also contains information about the surface. When all of this information is put into an image of the surface. You get a perfectly rectified aerial photo as you are collecting! And its already perfectly aligned with the elevation information to make the final basemap.

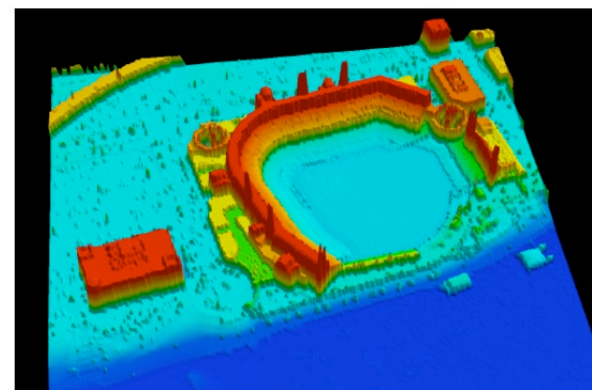


Figure 4. 3-D surface rendering of lidar data collected over a baseball stadium in Pittsburgh.

Accuracy and Resolution

The accuracy of lidar elevation data can be astounding. Typically it is better than 18cm rms error vertically. That's small enough to be able to detect the tread of a footpath relative to the surrounding forest floor! But there is a catch. Recall that some number of the points are lost when they hit tree tops. Those points are thrown out by the filtering software, leaving behind only the bare-earth returns. In order to be able to resolve (see) an object in the data there must be at least two samples across the width of the object (this is called Nyquist sampling). For example, let's say there is a 2-meter wide pit in the forest and we have collected lidar data with an average point spacing of 1 meter, we should be able to easily "see" the pit in the bare earth surface, provided not too many of those lidar returns were blocked completely by tree branches. A 1-meter wide pit in the same dataset would be very difficult to identify...it would blend into the noise. So you can see that a higher collected lidar point density is better for seeing small details on the ground. However, collecting more points requires that the plane move slower and the laser move faster, and more data takes more time to process. As we all know, time is money, so agencies collecting lidar data will only collect the minimum amount of data required to meet the specifications of a particular project. This might be high enough to make accurate contours of an area under tree canopy, but not high enough to see the interesting small details. So in this way, as with aerial photos, not all lidar datasets are equal, even though the individual data points themselves be highly accurate. I've found that its possible to make decent contours for 1:10000 orienteering maps from lidar with an average point spacing of up to 2m, but having 1m or better is ideal for the additional small details that it provides. I've also made basemaps using 3-4m sparsely sampled lidar data, but once you get into the 4m range you are at the same resolution as USGS topo maps. Lidar at this resolution lacks the fine detail required for orienteering maps, but contours derived from this data is more accurate than the USGS topographic maps, so its still more desirable in that respect.

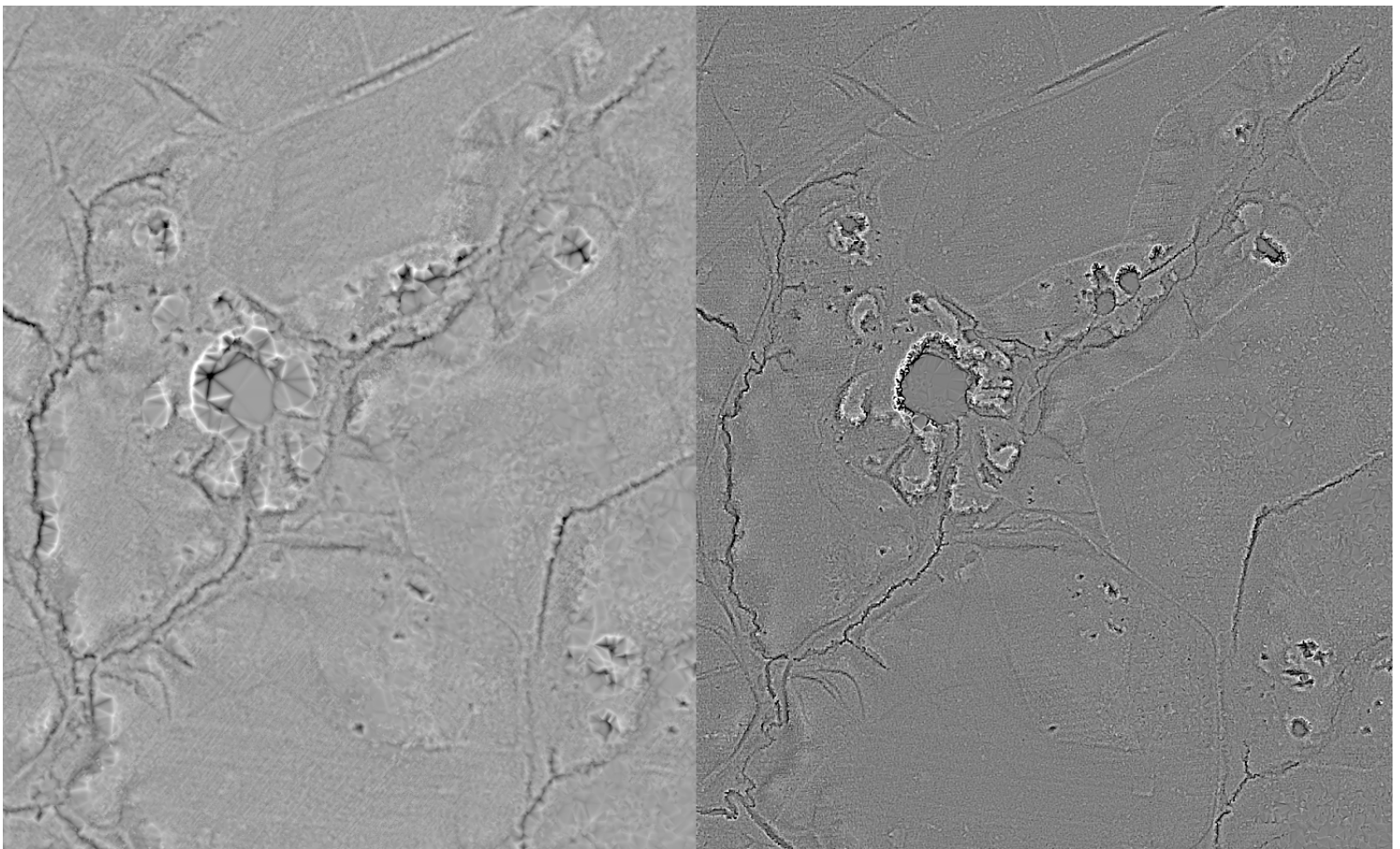


Figure 5a. (left) unsharp-mask filtered 2-meter average lidar point spacing of a section of the Mckeldin map in Maryland. (right) The same area, but with 1-meter average lidar point spacing.

Figure 5a shows a side-by-side comparison between 2-meter average posting lidar data on the left and 1-meter data on the right of a small section of the recent "Ran-it Granite" A-meet map in Maryland. Note the small depressions and large quarry with a pond in the middle. Figure 5b shows the same area of the final, field-checked orienteering map. If you look closely you can see most of the details in both lidar sets, but clearly the higher sample density set is much clearer. The 5-meter contours generated from both of these sets were nearly identical. The difference is all in the level of fine-detail visible.

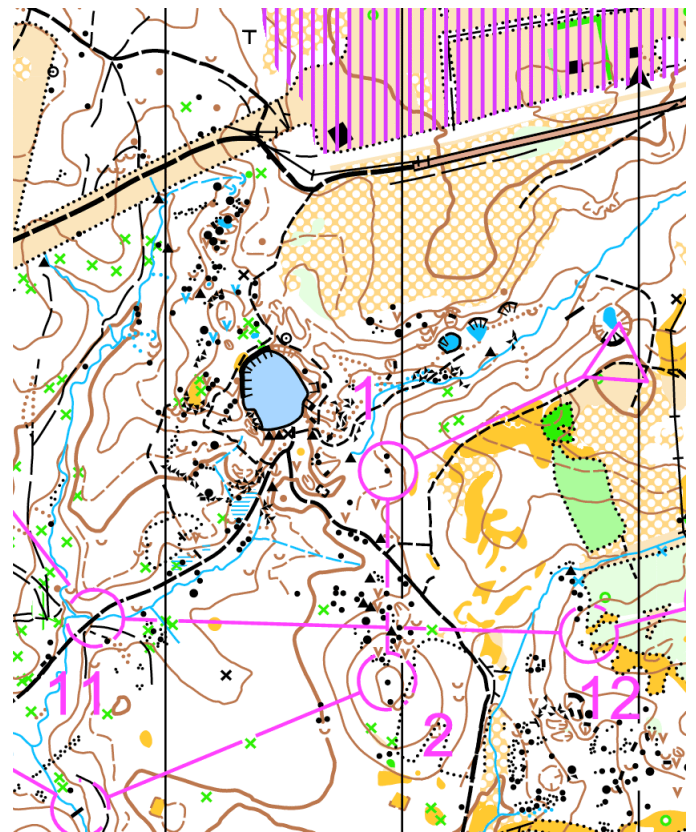


Figure 5b. Section of the final Orienteering map (after field checking) covering the area in figure 5a.

From Data to Paper

The contours derived from the bare-earth lidar points can be written directly to an OCAD file. Additional details can be added by using templates under the contours such as aerial photos from other sources, or the lidar intensity image (Fig 6). With some contrast enhancements, small details in the elevation data that are too small to show up in the contours can be seen directly in the bare-earth data. Using an image of these details as a template in OCAD allows them to be added by hand. Some of these details might be too small to make it onto the final orienteering map but can be extremely useful to the fieldchecker, as their positions and shapes are accurately known. Even if a detail seen in the bare-earth lidar is unidentifiable, at least the fieldchecker can go out in the terrain and make a simple determination of what the feature is and adjust it with the accurate positional information already included.

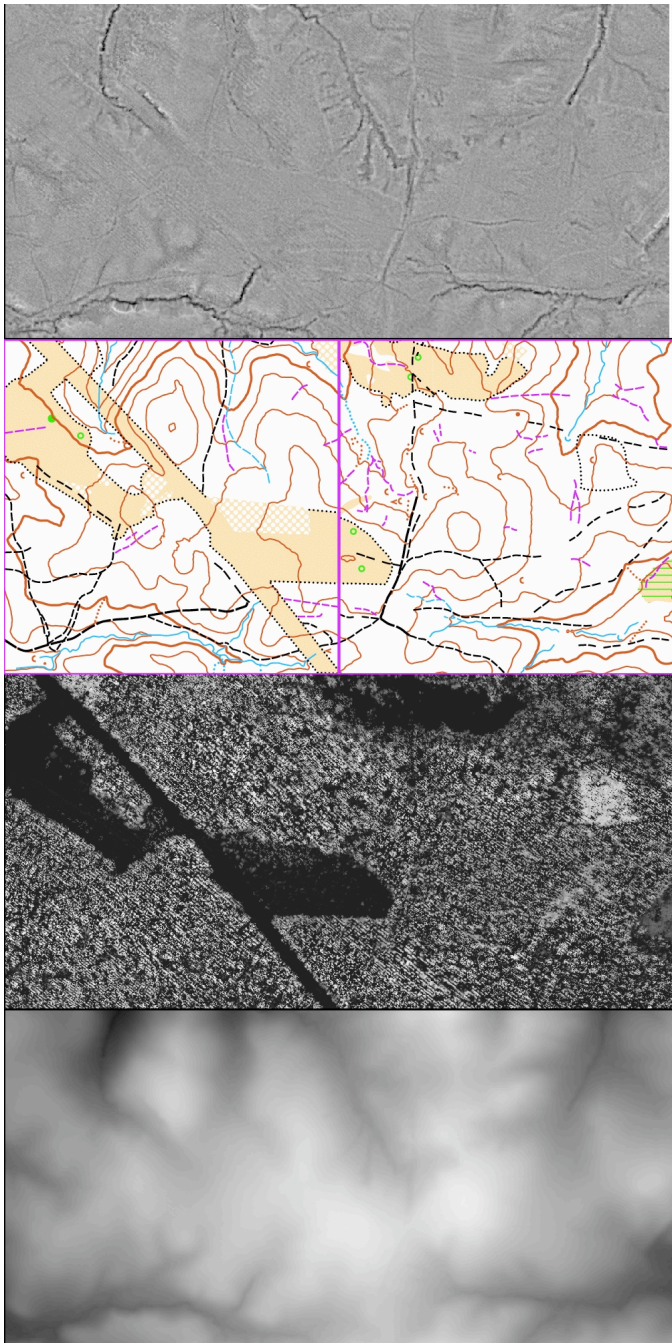


Figure 6. 4-panels of the same area: (bottom) raw bare-earth 2-meter lidar image - brighter is higher elevation, darker is lower, such as stream drainages. (2nd from bottom) vegetation height lidar image. Bright areas are high deciduous tree crowns, dark areas are open fields with no trees. Note the white patch, which is an area of pine plantation. Even though there are more returns from the thicker evergreen canopy, some ground returns do get through. (top) unsharp-masked (contrast enhanced) version of the bare-earth lidar in the bottom panel. This is the same data, only enhanced to show the fine detail more easily. (2nd from top) basemap made exclusively from the lidar dataset. No fieldwork has been performed at this point. Purple lines were used here to indicate weaker linear features which might just be low reentrant bottoms, but could possibly be trails or small ditches. See if you can spot the small depression under the pine plantation canopy.