



Range accuracy usually varies from 2cm to 20cm with respect to the measured range. The higher the range accuracy, the higher the quality of the point cloud representation of road surfaces, road furniture, buildings, trees and other objects of interest will be. After emission, the laser beam diverges and propagates as a cone, resulting in an elliptical footprint when the beam hits a surface. Capturing small objects at longer distances from the vehicle requires small footprints.

Point density is largely determined by the beam output rate, which is usually specified as points per second (pts/sec) emitted by the Lidar system. If the applications require high point densities, then the beam output rate is crucial. The smaller the angular resolution, which is usually specified for both vertical and horizontal directions, the denser the point cloud and thus the more detail is present. Usually, Lidar sensors capture the first and the strongest returns. These multi-return sensors result in denser point clouds and better object representations.

  
Figure 1: Selected Velodyne Lidar devices.

VFoV: Most spinning Lidar sensors have horizontal field of view (HFOV) coverage of 360°. Solid-state systems require three or more aligned sensors to obtain full 360° coverage. On the other hand, the larger the VFoV, the better the scene is covered.

The features of Lidar sensors discussed above largely determine the survey productivity of a mobile mapping system (MMS). A selection of Lidar systems that are potentially suited for mobile mapping (see Figure 1) have been categorized – based on the specifications given by the manufacturers – into four groups: very-high productivity, high productivity, adequate productivity and others. The specifications of the selected systems are listed in Table 1.

  
Table 1: Specifications of Lidar sensors as provided by the manufacturers.

[\(Click here for a high-resolution version of the table\)](#)

## Very-high Productivity (128 beams)

Three of the selected Lidar sensors have been placed in the top segment of very-high productivity. The main factor influencing productivity is the number of laser beams emitted simultaneously; currently, the maximum number of beams is 128.

With a total output rate of 2.6 million pts/sec for all 128 beams together, the [Ouster OS1-128](#) has the highest output rate of all selected systems. Its price and VFoV of 45° give it the edge over the other types. The other very-high productivity Ouster Lidars [OS0-128](#) and [OS2-128](#) are less suitable for the mobile mapping applications because of either shorter scanning ranges or narrower VFoV.

With a total output rate of 2.4 million pts/sec for all the 128 beams together, the [Velodyne Alpha Prime](#) scores as one of the best spinning devices. Compared to other 128-beam sensors, this system has a wide VFoV, a high number of returns and a long maximum range. With respect to size and weight, the Alpha Prime is one of the largest and heaviest systems.

The solid-state [Luminar](#) has the longest maximum range and an output rate of over half a million pts/sec. Since three devices are needed to achieve a 360° VFoV, the total output rate is 1.5 million pts/sec. Weighing in at 3.9kg, the system is relatively heavy.

## High Productivity (64 beams)

Four Lidar sensors have been categorized in this segment. Their productivity is lower because the number of laser beams emitted simultaneously is 64, which is half the number in the top segment. The spinning [Ouster OS1-64](#) has an output rate of 1.3 million pts/sec and a maximum range of 120m. The beams are distributed symmetrically around the horizontal plane and the VFoV is good. As a result, this system has many beneficial properties – especially when two Lidar sensors are mounted on the vehicle.

The [Ouster OS2-64](#) also has an output rate of 1.3 million pts/sec and its maximum range is 240m. The narrow VFoV and its larger size make it less suited for mobile mapping however. Both of these Ouster sensors are reasonably priced. Their beam wavelength of 850nm is less absorbed by water particles in the atmosphere, which means that both systems can operate efficiently under high humidity conditions.

Also in the high-productivity category are the Lidar systems from Chinese manufacturer Hesai. The maximum range of the [Hesai Pandar64](#) is 200m at 10% reflectivity, the output rate is 1,152,000 pts/sec and the VFoV is 40° with a resolution of 0.17°. However, the three Hesai systems listed in Table 1 distribute the beams irregularly (gradient) over the scene; they are mostly concentrated in the horizontal plane. This may affect the coverage and uniformity of point distribution.

The [Velodyne HDL-64E](#) has a comparable output rate and the vertical resolution of 0.4° is reasonable. The disadvantages are its weight, size and price. Figure 2 shows the scanning patterns of different Lidar devices in a closed rectangular space where they are orientated vertically without tilt.

  
Figure 2: Scan patterns of different Lidar sensors.

## Adequate Productivity (32 beams)

Three Lidar sensors have been categorized in this segment. Their productivity is lower than the very-high and high-productivity segments because the number of laser beams emitted simultaneously is 32.

The [Velodyne HDL-32](#) has a VFoV of 40° and a maximum range of 120m. It has a reasonable size, weight and power consumption and is used by mobile mapping companies such as [CycloMedia](#), [Topcon](#), [Maverick Teledyne Optech](#) and [Viametris vMS3D](#) (Figure 3).

The features of the recently released [Ouster OS1-32](#) are comparable to those of the Velodyne HDL32, but with a slightly lower output rate. The symmetrical angles above/below the horizon of the OS1-32 are beneficial for capturing above and below-ground objects. Considering its reasonable price this multibeam Lidar is a popular choice, especially when multiple devices are mounted in the MMS.

Except for the number of laser beams emitted, the features of the [Hesai Pandar40P](#) are similar to the high-productivity Pandar64.

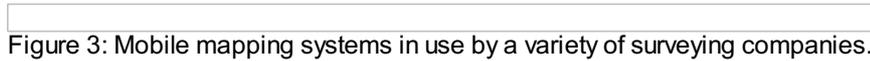


Figure 3: Mobile mapping systems in use by a variety of surveying companies.

## Others

There are several other Lidar sensors which may be particularly suited for indoor and unmanned aerial system (UAS) applications.

The [Quanergy M8](#) has a small horizontal angular resolution, captures up to three returns per pulse, has a VFoV of 20° and emits eight beams simultaneously.

The [Velodyne Puck](#) sensors (VLP-16, Hi-Res, Lite) have output rates of 300,000 pts/sec. Their maximum range, range accuracy, size, weight, power consumption and prices are reasonable, but their geometric/scanning properties are less adequate than the HDL-32.

The features of the [Hesai Pandar40](#) are similar to the Pandar40P but the VFoV of 23° is narrow. Mapping companies are using some of these Lidar sensors in their unmanned airborne systems and indoor mapping systems (Figure 4). For example, the Australian company Emesent has mounted the Velodyne VLP-16 on its [Hovermap](#) UAS (Figure 4a), and Viametris has mounted the VLP-16 (Figure 4b) on its backpack indoor mapping system.

The [C2L nebula-LP MMS](#) (Figure 4c) and the [GeoCue](#) UAS (Figure 4d) use Quanergy M8.

The maximum range of the Sense 30 – a solid-state sensor – is 21m, which is an impediment for outdoor applications.

The two Blickfeld solid-state sensors listed have a low output rate. The acquisition of dense point clouds requires thus long survey times.

The newly released ultra-wide-view Lidars from Ouster (namely OS0-32, OS0-64 and OS0-128) have a 90° VFoV which is highly efficient for autonomous driving. However, they are less relevant for mobile mapping applications because of their limited maximum scanning range of 20m @ 10% target reflectivity.

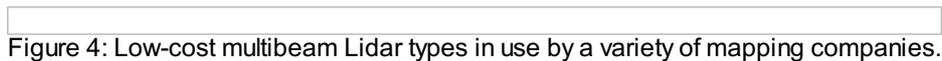


Figure 4: Low-cost multibeam Lidar types in use by a variety of mapping companies.

## Concluding remarks

Mobile mapping companies that want to conduct large-scale projects or achieve city-wide coverage may benefit from a single multibeam Lidar with high productivity or from integrating multiple Lidar devices from the very-high or high-productivity categories. Of course, the available budget will play a key role in the system choice. A wider VFoV combined with a longer scanning range, high output rate of points and better range accuracy will always be of significant importance when selecting the most suitable Lidar device for a mobile mapping system.

*Author's note: Lidar technology is rapidly evolving and new types are being released all the time. The information provided in this article was correct at the time of writing.*