LAS Extrabytes Implementation in *RIEGL* Software

WHITEPAPER

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1 INTRODUCTION

The intention of this document is to provide some background information about the implementation of extrabytes in the LAS exports of the *RIEGL* software RiPROCESS and RiSCAN PRO. We believe that adding valuable additional information provided by RIEGL instruments to each point of the point cloud, to the widely used LAS format provides useful benefit for further processing of Lidar data. We acknowledge the LAS format as being one of the major exchange formats in the Lidar industry and are committed to undertake the required efforts to make available the variety of information evolving from the latest developments of our instruments by means of the LAS standard.

1.1 REFERENCE

The actual implementation is based on the ASPRS document:

LAS SPECIFICATION VERSION 1.4 – R14
Revision Date 26 March 2019
Approved on November 14, 2011 and published by the American Society for Photogrammetry & Remote Sensing (www.asprs.org).

2 DEFINITIONS

The following overview of the definitions should provide some background information about the additional parameters provided by *RIEGL* sensors, to understand the idea behind it and how it could enhance the possibilities of post processing software making use of it.

2.1 BASICS: DECIBEL

The decibel (dB) is a logarithmic unit that indicates the ratio of a physical quantity (usually power or intensity) relative to a specified or implied reference level. A ratio in decibels is ten times the logarithm to base 10 of the ratio of two physical quantities. For example a ratio of 10 corresponds to 10 dB, ratios of 0.5, 20 and 100 to -3 dB, 13 dB and 20 dB, respectively.

2.2 ATTRIBUTE: INTENSITY

Up to now the intensity value is a common attribute beside the geometry information in a LAS file:
"The intensity value is the integer representation of the pulse return magnitude. This value is optional and system specific. […]Intensity, when included, is always normalized to a 16 bit, unsigned value by multiplying the value by 65,536/(intensity dynamic range of the sensor)."
This citation taken from LAS SPECIFICATION VERSION 1.4 – R14, page 16 defines pretty well

how intensity values in LAS files have to be interpreted. According to the specification intensity is a unitless and scaled attribute. When reading the intensity in a LAS file, without knowing about its creation history a correct interpretation is very difficult.
To overcome this shortcoming *RIEGL* will provide the amplitude and reflectance (where available) in all further LAS exports.

2.3 ATTRIBUTE: AMPLITUDE

The amplitude of the echo signal reaching the laser scanner depends on a number of parameters, including system parameters like the emitted laser pulse peak power and the receiver aperture, but also including target parameters like the target's reflectance (more precise the target's laser radar cross section including also the target size and the directivity of the target's reflection) and range. By means of a careful calibration during manufacturing, *RIEGL*'s V-Line instruments provide for every detected echo signal an amplitude reading which reflects the amplitude of the optical echo signal. The amplitude is given relative to the amplitude of an echo signal at the detection threshold of the instrument. Thus, the value of the amplitude reading is a ratio, given in the units of decibel (dB). This logarithmic measure covers the wide dynamic range of *RIEGL* instrument perfectly, usually above 60 dB, i.e., a ratio of more than 1 : 1,000,000.

$$A_{dB} = 10 * log\left(\frac{P_{echo}}{P_{DL}}\right)$$ ...Amplitude formula

A_{dB} ...Amplitude in decibel, P_{echo} ...optical input power, P_{DL} ...minimum detectable input power

Therefore signal strength ratios in dB between different targets can be obtained simply by calculating the difference between the corresponding amplitude values:

$$10 * log\left(\frac{P_{echo,1}}{P_{echo,2}}\right) = A_{dB,1} - A_{dB,2}$$

2.4 ATTRIBUTE: REFLECTANCE

The calibrated amplitude as described above still suffers from the fundamental range dependence of the echo signal detected by the receiver, making the interpretation of scan data difficult, especially when combining data from different laser scanners and/or different scan positions. This can be resolved by providing not only the calibrated amplitude but also the relative reflectance. Reflectance is a target property and refers to the fraction of incident optical power that is reflected by that target at a certain wavelength. The reflectance is always a positive real number. *RIEGL*'s V-Line instruments provide a relative reflectance reading for each detected target as an additional attribute. The relative reflectance provided is a ratio of the actual amplitude of that target to the amplitude of a white flat target at the same range, orientated orthonormal to the beam axis, and with a size in excess of the laser footprint. The actual reflectance reading is given in decibel (dB). To be more precise, the reflectance reading of *RIEGL*'s V-Line instruments takes also the directivity of the reflection into account and can be interpreted as the normalized laser radar cross section – normalized by the laser footprint area. Negative values hint to diffusely reflecting targets, whereas positive values are usually retro-reflecting targets. A relative reflectance higher than 0 dB results from targets reflecting with a directivity different from that of a lambertian reflector. Such targets may be reflecting foils, cornercube arrays, license plates, traffic signs or mirror-like objects as, e.g. window panes or blank metal aligned perpendicular to the measurement beam.

$$\rho_{rel} = A_{dB} - A_{dB,Ref}(R)$$ …formula for relative reflectance

ρ_{rel} …relative reflectance in dB, A_{dB} …calibrated Amplitude, $A_{dB,Ref}$ (R) …Amplitude of a reference target at range R

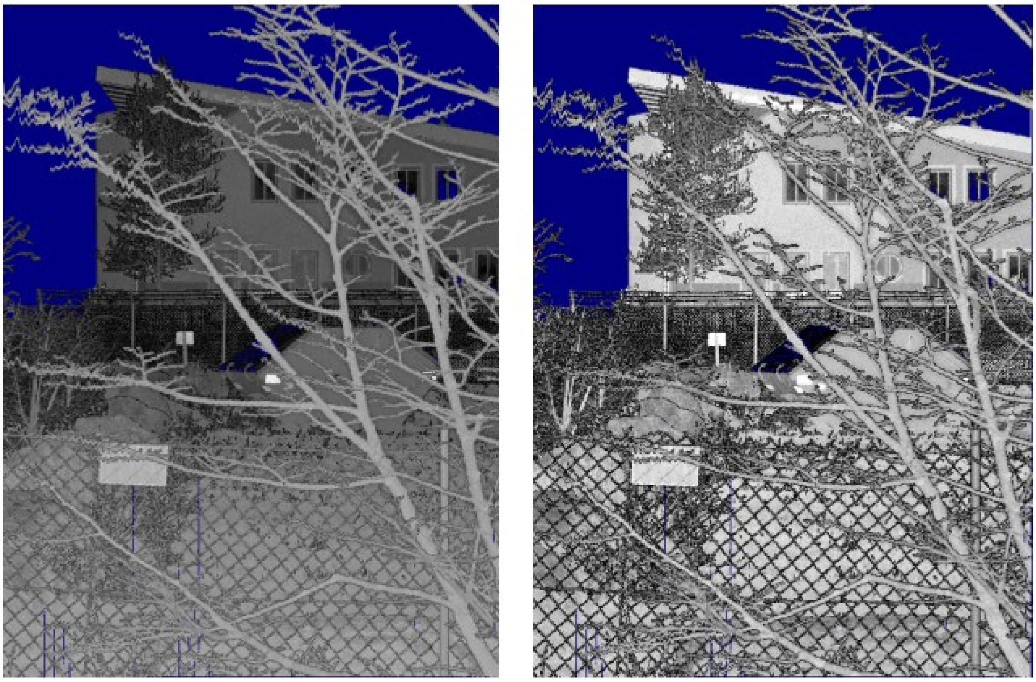
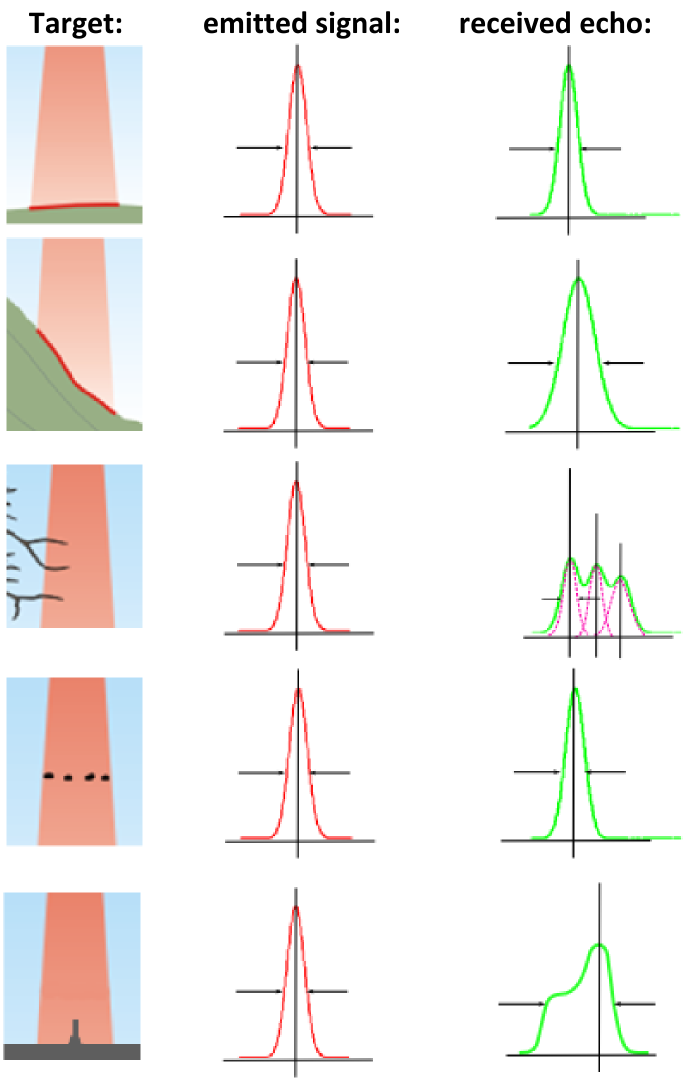


Figure 1: Left: Grey scale encoding of point cloud according to calibrated amplitude. Range of encoding 0 dB to 50 dB above detection threshold. Note that brightness decreases from near objects to far objects. Right: Grey scale encoding of point cloud according to reflectance of target. Range of encoding is -20 dB to 3 dB with respect to white diffuse target. Note that brightness is nearly independent from distance. Targets with a reflectance above 3 dB are shown in white, targets below -20 dB are black.

2.5 ATTRIBUTE: PULSE WIDTH

The pulse width is defined as full width at half maximum of the received echo signal and is measured in nanoseconds (ns).



Flat target: the pulse width of the received echo signal is similar to the pulse width of the emitted signal.

Slope target: the pulse width of the received echo signal is widened compared to the pulse width of the emitted signal.

Multiple targets: The received echo signals of the three targets overlap. The spatial distribution exceeds the detection threshold.

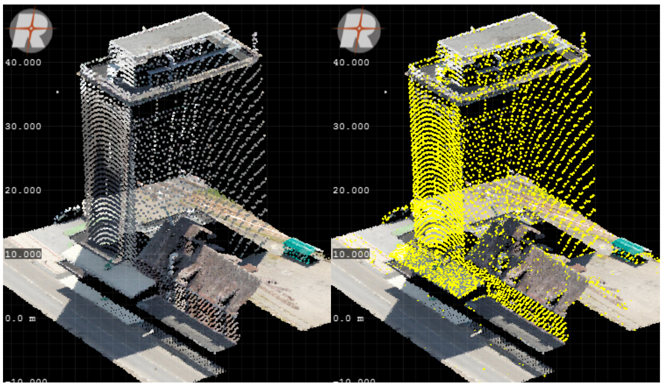
Received echo signals of objects at the same range overlap to a single echo signal. The small variation in range yield a slight widening of the echo signal.

Merged targets: the pulse width of the received echo signal is dramatically widened compare to the pulse width of the emitted signal.

Similar to the pulse shape deviation described below, the pulse width can be regarded as a quality indicator of received echo signals. As the figure above indicates the width of a received echo signals is depending on the geometry of the hit target.

2.6 ATTRIBUTE: PULSE SHAPE DEVIATION

RIEGL V-Line instruments make use of echo digitization and on-line waveform processing by digital signal processing. Beside target range and amplitude, the pulse shape of the echo signal is compared to the pulse shape representing the so-called system response. The pulse shape deviation can be interpreted as the comparison of the area below the shape curve and is one of the additional attributes to each point of the point cloud. Low values indicate that the echo pulse shape does not deviate significantly from the system response. High values hint to echo signals with a significantly different pulse shape, which may arise from, e.g., merging echo pulses from several targets hit by the laser beam at only slightly different ranges or extremely slanting angles of incident. This effect could be used, e.g., to detect vertical surfaces from ALS Lidar data, as indicated by the right image.



Left side: true colour representation of a pointcloud, right side: points filtered by deviation

3 RIEGL ATTRIBUTES WRITTEN TO EXTRABYTES

The attributes described above a calculated, when processing *RIEGL* scan data with RiPROCESS and RISCAN PRO. Depending on the laserscanner, all or some of the attributes are available and can be exported to LAS in the following structure. See the appendix for a list of available attributes per scanner model.

3.1 OVERVIEW

name	data_type	No data	min	max	scale	Description
Amplitude	4 (short)	-32768	-32767	32767	0.01	Echo signal amplitude [dB]
Reflectance	4 (short)	-32768	-32767	32767	0.01	Echo signal reflectance [dB]
Deviation	4 (short)	-1	0	32767	-	Pulse Shape Deviation [1]
PulseWidth	3 (unsigned short)	0	1	65535	0.1	Full width at half maximum [ns]

3.2 RECORD DEFINITIONS

This section describes the structure of the extrabytes as it is written to the LAS format by the export function of *RIEGL* software.

3.2.1 extrabytes structure for amplitude

RESERVED	00 00	
DATA_TYPE	04	// (signed) short
OPTIONS	0F	// bit0(no_data), bit1(min), // bit2(max), bit3(scale)
NAME	41 6D 70 6C 69 74 75 64 65 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// 'Amplitude'
UNUSED	00 00 00 00	
NO_DATA[3]	00 80 FF FF FF FF FF FF 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [-32768, unused, unused]
MIN[3]	01 80 FF FF FF FF FF FF 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [-32767, unused, unused]
MAX[3]	FF 7F 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [32767, unused, unused]
SCALE[3]	7B 14 AE 47 E1 7A 84 3F 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [0.01, unused, unused]
OFFSET[3]	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [unused, unused, unused]
DESCRIPTION	45 63 68 6F 20 73 69 67 6E 61 6C 20 61 6D 70 6C 69 74 75 64 65 20 5B 64 42 5D 00 00 00 00 00 00	// 'Echo signal amplitude // [dB]'

3.2.2 extrabytes structure for reflectance

RESERVED	00 00	
DATA_TYPE	04	// (signed) short
OPTIONS	0F	// bit0(no_data), bit1(min), // bit2(max), bit3(scale)
NAME	52 65 66 6C 65 63 74 61 6E 63 65 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// 'Reflectance'
UNUSED	00 00 00 00	
NO_DATA[3]	00 80 FF FF FF FF FF FF 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [-32768, unused, unused]
MIN[3]	01 80 FF FF FF FF FF FF 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [-32767, unused, unused]
MAX[3]	FF 7F 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [32767, unused, unused]
SCALE[3]	7B 14 AE 47 E1 7A 84 3F 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [0.01, unused, unused]
OFFSET[3]	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [unused, unused, unused]
DESCRIPTION	45 63 68 6F 20 73 69 67 6E 61 6C 20 72 65 66 6C 65 63 74 61 6E 63 65 20 5B 64 42 5D 00 00 00 00	// 'Echo signal reflectance // [dB]'

3.2.3 extrabytes structure for pulse shape deviation

RESERVED	00 00	
DATA_TYPE	04	// (signed) short
OPTIONS	07	// bit0(no_data), bit1(min), // bit2(max)
NAME	44 65 76 69 61 74 69 6F 6E 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// 'Deviation'
UNUSED	00 00 00 00	
NO_DATA[3]	FF FF FF FF FF FF FF FF 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [-1, unused, unused]
MIN[3]	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [0, unused, unused]
MAX[3]	FF 7F 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [32767, unused, unused]
SCALE[3]	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [unused, unused, unused]
OFFSET[3]	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [unused, unused, unused]
DESCRIPTION	50 75 6C 73 65 20 73 68 61 70 65 20 64 65 76 69 61 74 69 6F 6E 00 00 00 00 00 00 00 00 00 00 00	// 'Pulse shape deviation'

3.2.4 extrabytes structure for pulse width

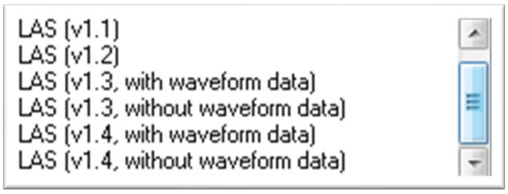
RESERVED	00 00	
DATA_TYPE	03	// unsigned short
OPTIONS	0F	// bit0(no_data), bit1(min), // bit2(max), bit3(scale)
NAME	50 75 6C 73 65 20 77 69 64 74 68 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// 'Pulse width'
UNUSED	00 00 00 00	
NO_DATA[3]	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [0, unused, unused]
MIN[3]	01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [1, unused, unused]
MAX[3]	FF FF 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [65535, unused, unused]
SCALE[3]	9A 99 99 99 99 99 B9 3F 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [0.1, unused, unused]
OFFSET[3]	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	// [unused, unused, unused]
DESCRIPTION	46 75 6C 6C 20 77 69 64 74 68 20 61 74 20 68 61 6C 66 20 6D 61 78 69 6D 75 6D 20 5B 6E 73 5D 00	// 'Full width at half maximum // [ns]'

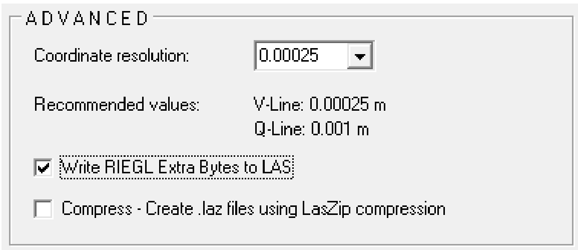
4 IMPLEMENTATION IN RIPROCESS

RiPROCESS is the software package for Waveform analysis, scan data adjustment, georeferencing and filtering of airborne and mobile laser scan data developed by *RIEGL*. The software calculates the attributes Amplitude, Reflectance, Pulse width and Pulse Shape deviation in accordance with the definitions in section 2.
As the software is designed to process data of all *RIEGL* sensors for kinematic data acquisition, it comes with various options to provide utmost user control. Therefore the availability of the additional point attributes may vary according to user settings. This has to be taken into account for the LAS export.

4.1 EXPORT DIALOG IN RIPROCESS

When exporting data from RiPROCESS the user can select from different LAS format version.
Actually the software supports the LAS 1.1, 1.2, 1.3 and 1.4 format versions.





Through the advanced settings tab the user can check the activation of the extrabytes handling. If checked the extrabytes will be exported according to the availability (sensor dependent) and the selected version automatically.

4.2 BACKWARD COMPATIBILITY

As the extrabytes structure exists since the LAS 1.1 format, the existing export functions were extended to make the additional attributes available to former versions of LAS as well. For compatibility reasons to existing LAS readers the information provided by the extrabytes will not replace existing attributes. For instance the intensity value will remain in the exports from LAS 1.1 to LAS 1.3 and LAS 1.4 with the amplitude or reflectance being added through the extrabytes. The compatibility matrix below indicates the available extrabytes for the different format versions. Please note: All versions will contain the VLR Header describing the meaning of the extrabytes.

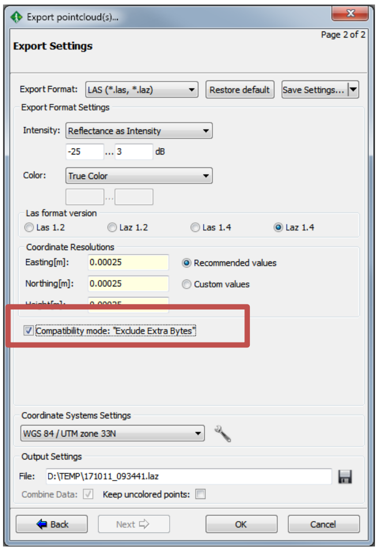
	VLR Header	Amplitude	Reflectance	Pulse width	Deviation
LAS 1.1	✓	✓	✓	✓	✓
LAS 1.2	✓	✓	✓	✓	✓
LAS 1.3	✓	✓	✓	✓	✓
LAS 1.4	✓	✓	✓	✓	✓

5 IMPLEMENTATION IN RISCAN PRO

RiSCAN PRO is the *RIEGL* processing package for terrestrial / static laser scan data. Static laser scanning is typically done by setting up a laser scanner on a tripod. In contrast to airborne and mobile (kinematic) laser scanning, the instrument is not moved during the data acquisition, but rotates around a frame axis. As the acquisition of static laser scan data significantly differs from the methods of kinematic laser scanning, some of the attributes defined in the LAS specification can't be written accordingly.
As a matter of fact there is no edge of flight line flag and the scan angle or scan angle rank is not representative, as static scans involve 2 scan angles (line angle and frame angle).
Despite these shortcoming LAS is recognised as the most common denominator in the terms of LiDAR data exchange and is therefore also supported in *RIEGL*'s terrestrial laser scanning software products RiSCAN PRO, RiSOLVE and RiMINING.

5.1 EXPORT DIALOG IN RISCAN PRO

RiSCAN PRO supports the export of LAS versions 1.2 and 1.4 and LAZ version 1.2
LAS data will be written with extrabytes by default. In case the further processing software doesn't provide extrabytes support, it can be disabled by checking the Compatibility mode: "exclude extrabytes" option.



5.2 BACKWARD COMPATIBILITY

RiSCAN PRO supports the export of LAS version 1.2. and 1.4.
The compatibility matrix below indicates the available extrabytes for the different format versions. Please note: All versions will contain the VLR Header describing the meaning of the extrabytes.

	VLR Header	Amplitude	Reflectance	Pulse width	Deviation
LAS 1.2	✓	✓	✓		✓
LAS 1.4	✓	✓	✓		✓

6 APPENDIX

6.1 EXTRABYTES ATTRIBUTES BY SCANNER MODEL

Note: Depending on user settings not all attributes may be available in a specific dataset.

6.1.1 Kinematic laser scanning

Model	Attributes available			
	A [1]	R [2]	PW [3]	PSD [4]
VQ-1560i and VQ-1560i- DW	✓	✓	✓	✓
LMS-Q1560	✓		✓	
LMS-Q1560i	✓	✓	✓	
VQ-880-G, VQ-880-GH, VQ-880-G II	✓	✓		✓
VQ-840-G	✓	✓		✓
VQ-780i	✓	✓	✓	✓
LMS-Q780	✓	✓	✓	
LMS-Q680i	✓		✓	
VQ-580, VQ-580 II	✓	✓		✓
VQ480, VQ-480 II	✓	✓		✓
VQ-450	✓	✓		✓
VQ-250	✓	✓		✓
VUX-240	✓	✓		✓
VUX-1LR, VUX-1HA, VUX-1UAV	✓	✓		✓
miniVUX-1UAV, miniVUX-1DL	✓	✓		✓

[1] Amplitude, [2] Reflectance, [3] PulseWidth, [4] PulseShapeDeviation

6.1.2 Static laser scanning

Model	Attributes available			
	A [1]	R [2]	PW [3]	PSD [4]
VZ-6000	✓	✓		✓
VZ-4000	✓	✓		✓
VZ-2000, VZ-2000i	✓	✓		✓
VZ-400, VZ-400i	✓	✓		✓
VZ-200	✓	✓		✓

[1] Amplitude, [2] Reflectance, [3] PulseWidth, [4] PulseShapeDeviation