High-Performance Online Waveform Processing Airborne LiDAR Scanning Module for Integration with Third-Party Camera Systems

RIEGL VQ-680 OEM

- *high pulse repetition rates of up to 2.4 MHz*
- *up to 2 MHz measurements on the ground*
- *forward / nadir / backward scan directions at +20/+10/0/-10/-20 degrees*
- *wide field of view of 60 degrees*
- *multiple target capability*
- *online waveform processing*



The VQ-680 OEM is a compact airborne LiDAR scanner module designed for integration with large-format photogrammetric aerial camera systems that are configured for urban mapping applications. The VQ-680 OEM's form factor has been optimized to provide a compact scanner with a small exit aperture, given the limited space in, e.g., photogrammetric oblique camera configurations.

The LiDAR scanner module includes an innovative scanning mechanism that provides forward, nadir, and backward scan lines at +20/+10/0/-10/-20 degrees in the flight direction. In combination with a wide horiontal field of view of 60 degrees a regular point spacing for each viewing direction is generated, enabling exceptional coverage of vertical structures such as building facades, as well as coverage at the bottom of narrow street canyons with little to no shadowing.

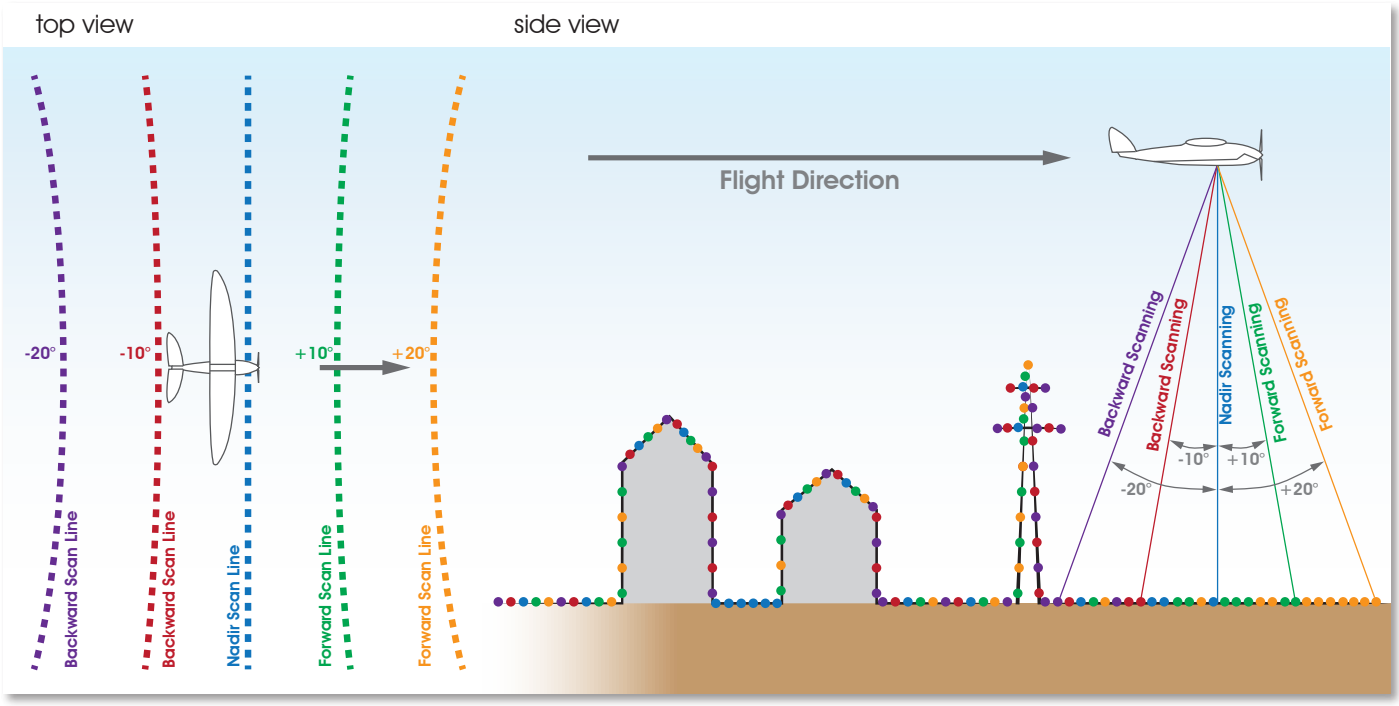
The operational envelope ranges from typical flying altitudes of 1000 m AGL at a pulse repetition rate of 2.4 MHz (~ 24 pts/m^2 at 120 kts), up to 2300 m AGL at a PRR of 300 kHz for targets with reflectivity in excess of 20%. Electrical interfaces comprise of a power supply, PPS and NMEA time synchronization, and a laser safety connector. Scan data is stored on an external PC via Gigabit Ethernet, which is also used for configuring and controlling the laser scanner via RiACQUIRE, *RIEGL*'s versatile data acquisition software featuring a GUI, real-time data visualization and remote control capabilities.

A sturdy mechanical interface enables mounting the LiDAR module inside a camera system rigidly connected with the IMU/GNSS system and various camera modules.

Applications:
- *Mapping of Complex Urban Environments*
- *City Modeling*
- *Ultra-High Resolution Mapping*
- *Oblique Mapping of Vertical Structures*
- *Corridor Mapping*

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LASER MEASUREMENT SYSTEMS

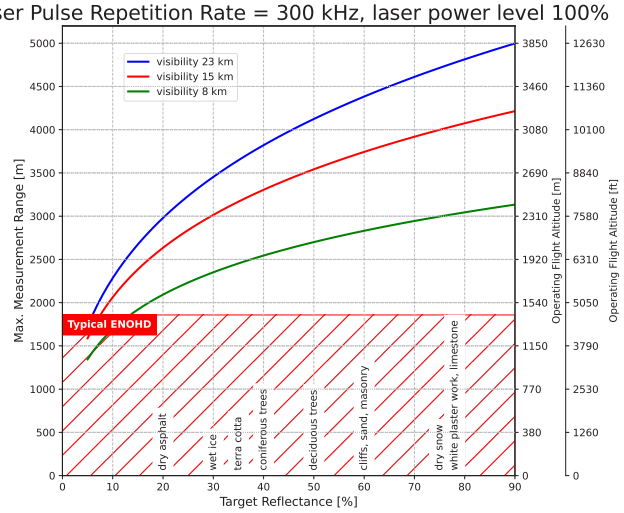


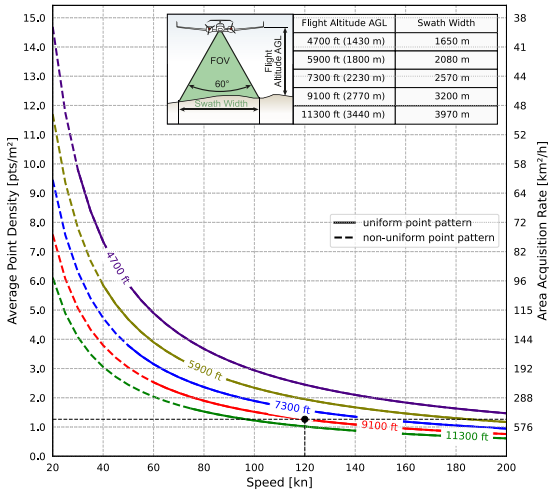
The *RIEGL* VQ-680 OEM offers a sophisticated, multi-axis scan geometry consisting of five parallel scan lines per scanner rotation, but with each scan line having its own unique scan direction. The scan directions change consecutively from nadir, to +10 and +20 degrees forward, and to -10 and -20 degrees backward. This scan geometry provides superior coverage of vertical features ahead of and behind the sensor, creating best-of-class 3D LiDAR data sets.
This is of value in urban, forestry and asset mapping applications where wholly complete coverages of vertical and planimetric features are now possible. By also maintaining a nadir scan direction, the new VQ-680 OEM excels at city mapping applications and digital twins whereby inner courtyards and deep urban canyons are effectively mapped with little to no occlusions within the data sets.

	Field of View		
Cross Flight Direction	± **30 deg** (i.e. 60 deg HFOV)		
In-Flight Direction (at swath center)	**nadir**	± **10 deg**	± **20 deg**
In-Flight Direction (at swath edge)	**nadir**	± **11.5 deg**	± **22.8 deg**

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Laser Pulse Repetition Rate = 300 kHz, laser power level 100%

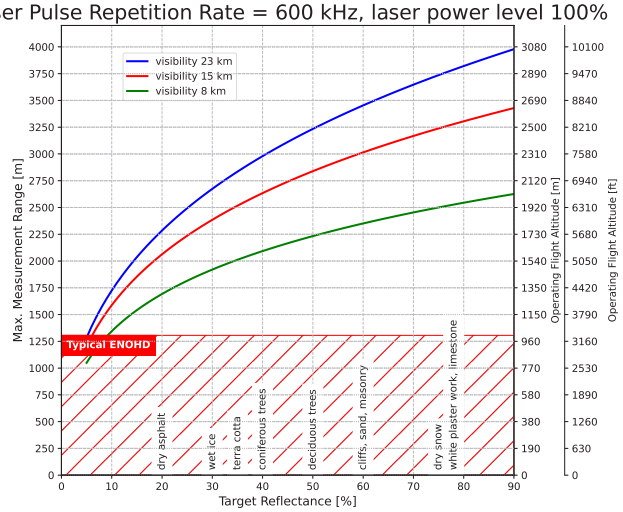


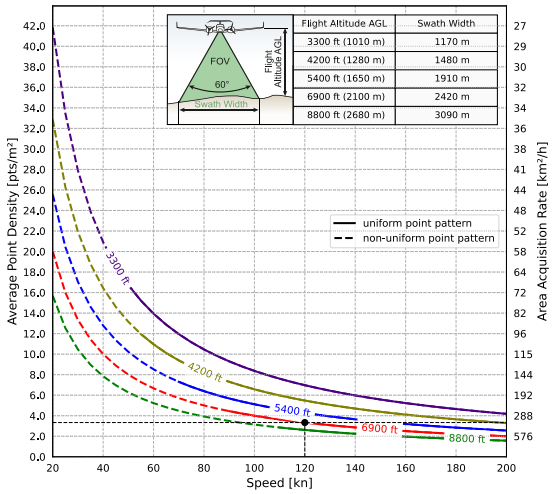


Example: VQ-680 OEM at 300,000 pulses/sec, laser power level 100%
Altitude = 9,100 ft AGL, Speed 120 kn

Results: Point Density ~ 1.26 pts/m²
Area Acquisition Rate ~ 456 km²/h

Laser Pulse Repetition Rate = 600 kHz, laser power level 100%



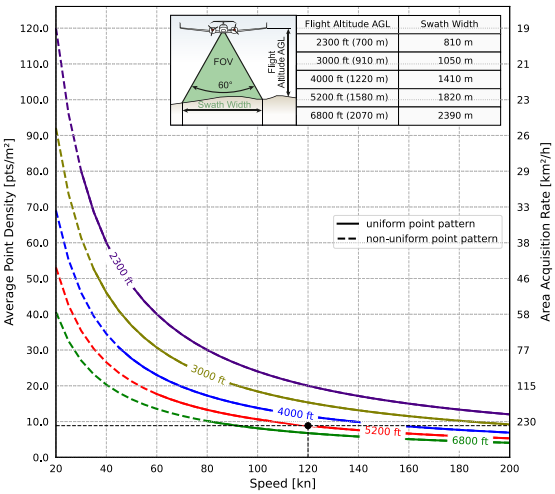


Example: VQ-680 OEM at 600,000 pulses/sec, laser power level 100%
Altitude = 6,900 ft AGL, Speed 120 kn

Results: Point Density ~ 3.34 pts/m²
Area Acquisition Rate ~ 345 km²/h

Laser Pulse Repetition Rate = 1200 kHz, laser power level 100%





Example: VQ-680 OEM at 1,200,000 pulses/sec, laser power level 100%
Altitude = 5,200 ft AGL, Speed 120 kn

Results: Point Density ~ 8.85 pts/m²
Area Acquisition Rate ~ 260 km²/h

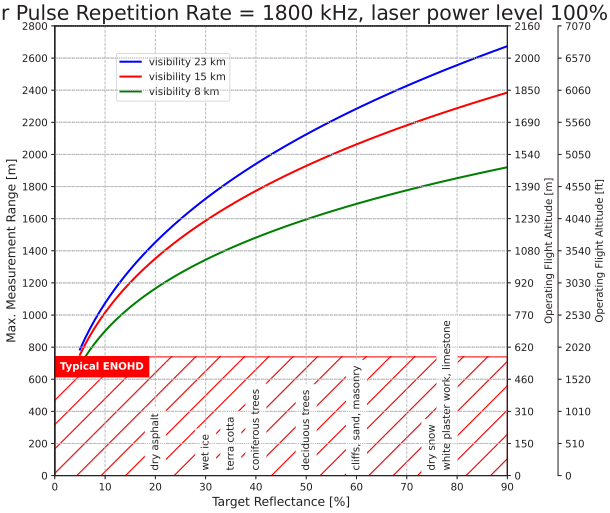
The following conditions are assumed for the Operating Flight Altitude AGL

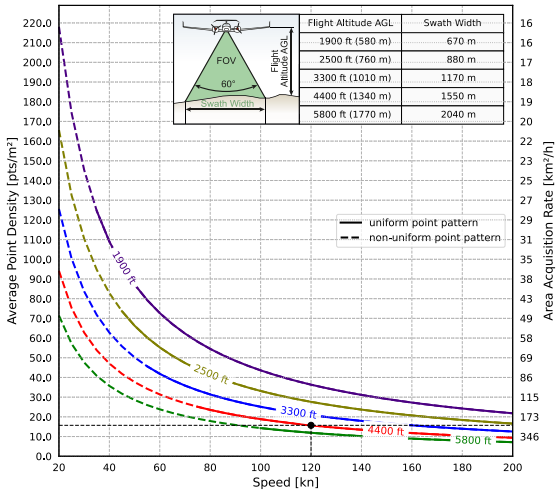
- ambiguity resolved by multiple-time-around (MTA) processing
- roll angle ±5°
- target size ≥ laser footprint
- average ambient brightness
- operating flight altitude given at a FOV of +/- 37.5°

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Maximum Measurement Range & Point Density *RIEGL* VQ-680 OEM

Laser Pulse Repetition Rate = 1800 kHz, laser power level 100%

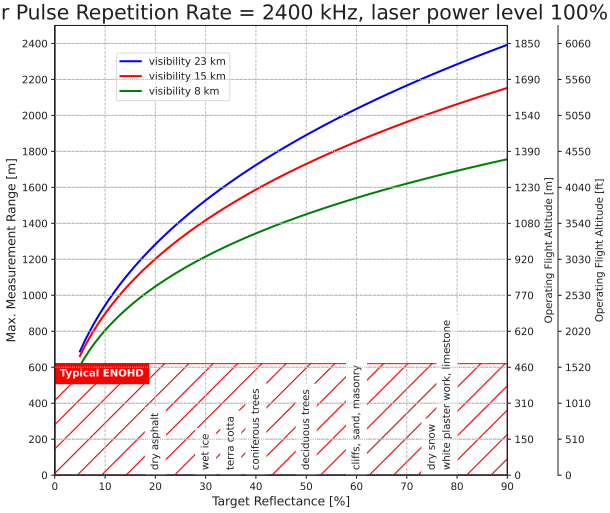


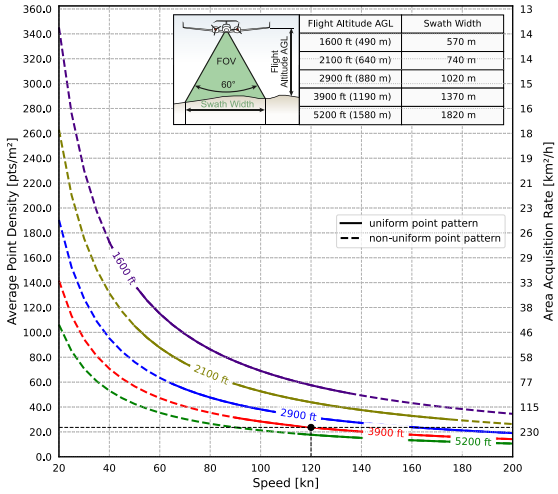


Example: VQ-680 OEM at 1,800,000 pulses/sec, laser power level 100%
Altitude = 4,400 ft AGL, Speed 120 kn

Results: Point Density ~ 15.69 pts/m²
Area Acquisition Rate ~ 220 km²/h

Laser Pulse Repetition Rate = 2400 kHz, laser power level 100%

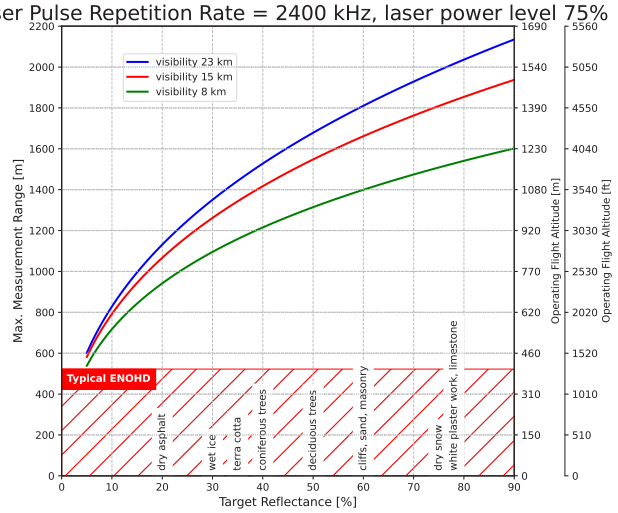


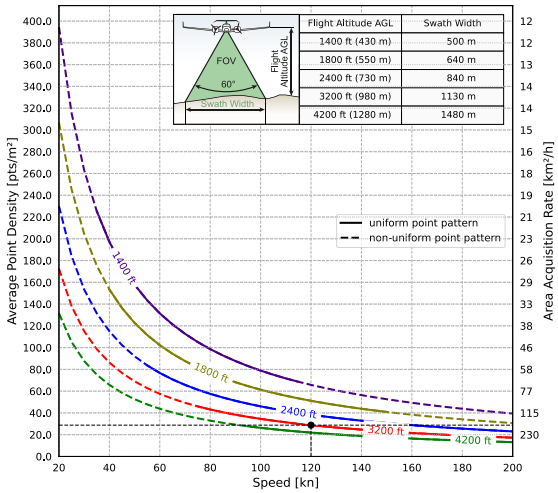


Example: VQ-680 OEM at 2,400,000 pulses/sec, laser power level 100%
Altitude = 3,900 ft AGL, Speed 120 kn

Results: Point Density ~ 23.6 pts/m²
Area Acquisition Rate ~ 195 km²/h

Laser Pulse Repetition Rate = 2400 kHz, laser power level 75%





Example: VQ-680 OEM at 2,400,000 pulses/sec, laser power level 75%
Altitude = 3,200 ft AGL, Speed 120 kn

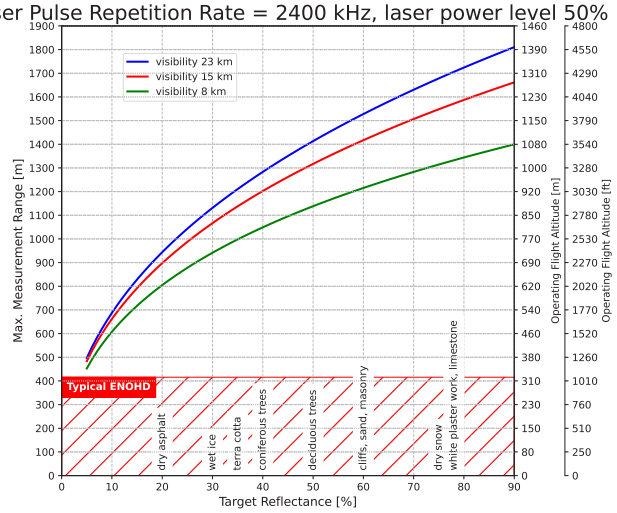
Results: Point Density ~ 28.77 pts/m²
Area Acquisition Rate ~ 160 km²/h

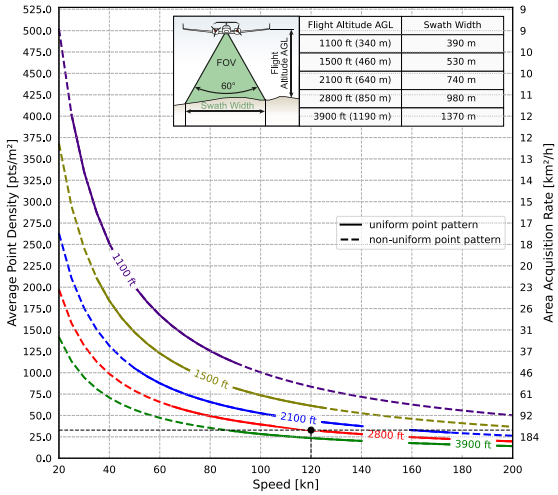
The following conditions are assumed for the Operating Flight Altitude AGL

- ambiguity resolved by multiple-time-around (MTA) processing
- roll angle ±5°
- target size ≥ laser footprint
- average ambient brightness
- operating flight altitude given at a FOV of +/- 37.5°

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Laser Pulse Repetition Rate = 2400 kHz, laser power level 50%

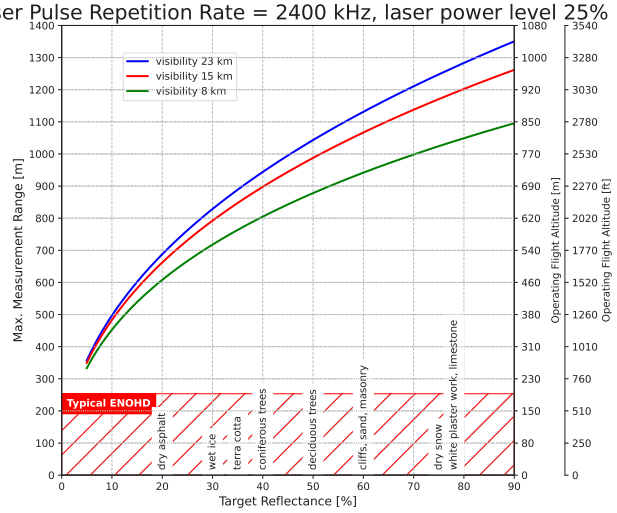


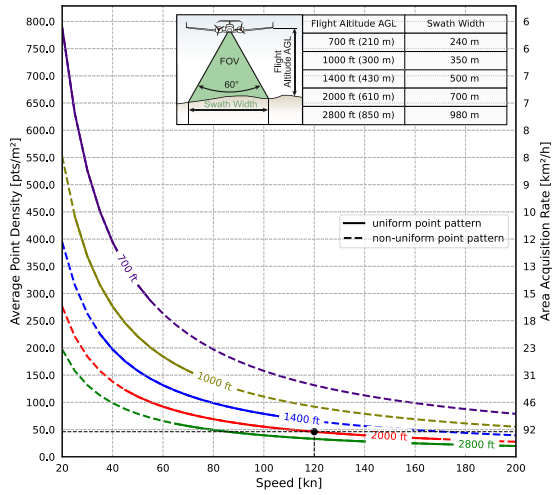


Example: VQ-680 OEM at 2,400,000 pulses/sec, laser power level 50%
Altitude = 2,800 ft AGL, Speed 120 kn

Results: Point Density ~ 32.88 pts/m²
Area Acquisition Rate ~ 140 km²/h

Laser Pulse Repetition Rate = 2400 kHz, laser power level 25%

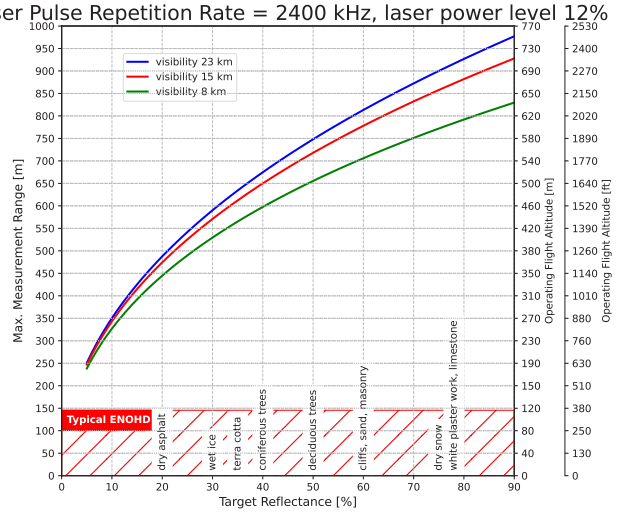


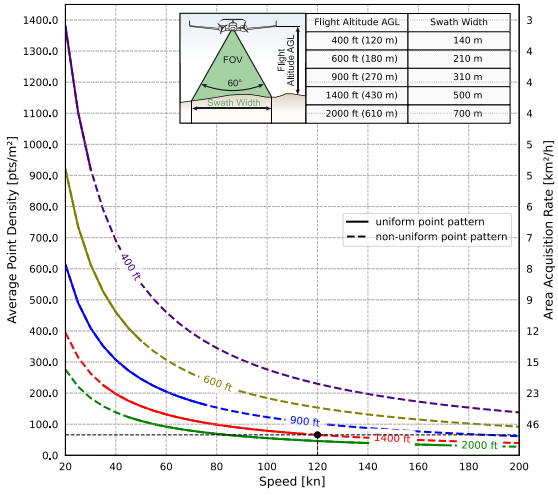


Example: VQ-680 OEM at 2,400,000 pulses/sec, laser power level 25%
Altitude = 2,000 ft AGL, Speed 120 kn

Results: Point Density ~ 46.03 pts/m²
Area Acquisition Rate ~ 100 km²/h

Laser Pulse Repetition Rate = 2400 kHz, laser power level 12%





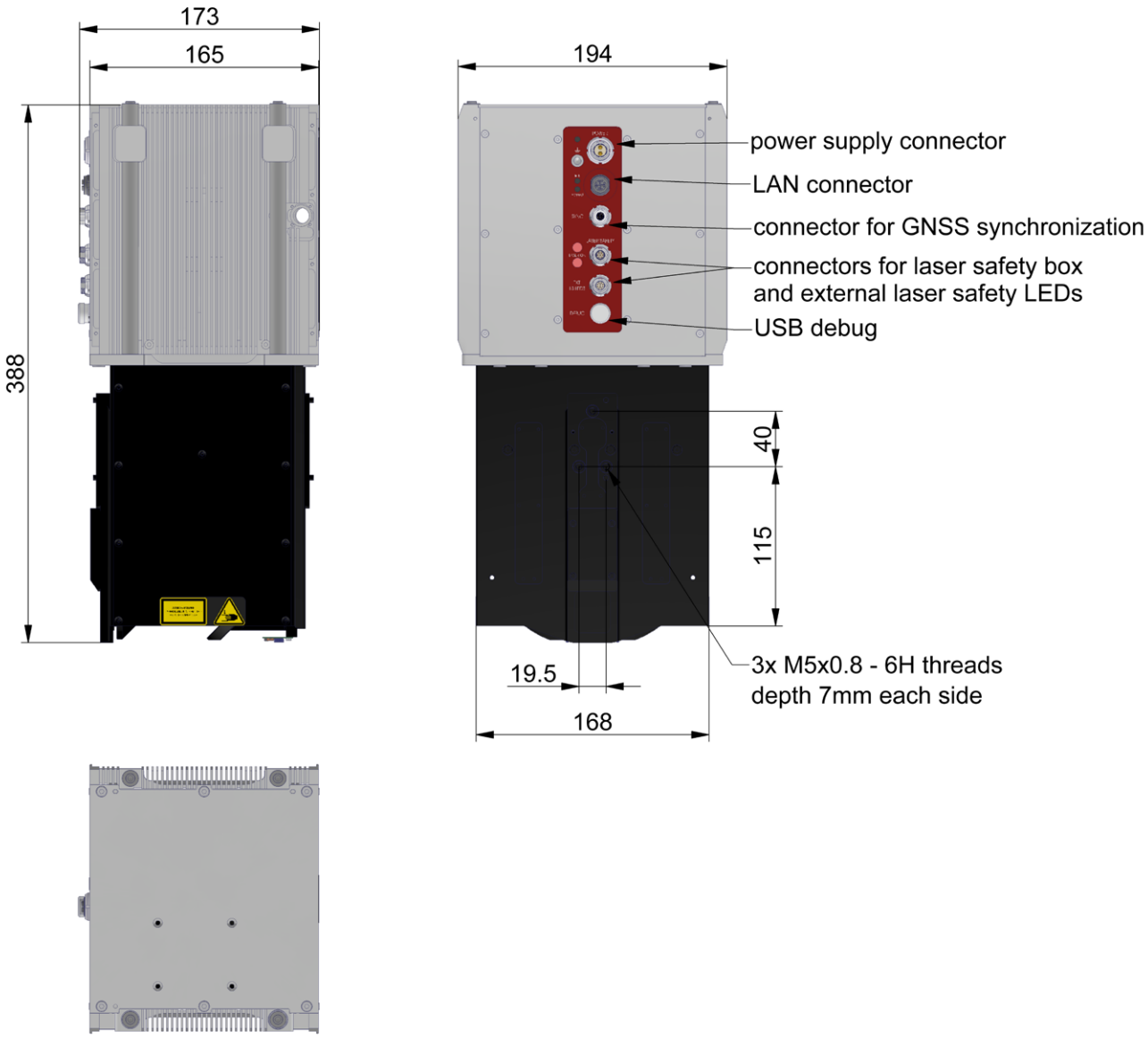
Example: VQ-680 OEM at 2,400,000 pulses/sec, laser power level 12%
Altitude = 1,400 ft AGL, Speed 120 kn

Results: Point Density ~ 65.75 pts/m²
Area Acquisition Rate ~ 70 km²/h

The following conditions are assumed for the Operating Flight Altitude AGL

- ambiguity resolved by multiple-time-around (MTA) processing
- roll angle ±5°
- target size ≥ laser footprint
- average ambient brightness
- operating flight altitude given at a FOV of +/- 37.5°

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all dimensions in mm

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Laser Product Classification

Class 3B Laser Product according to IEC 60825-1:2014

The following clause applies for instruments delivered into the United States: Complies with 21 CFR 1040.10 and 1040.11 except for conformance with IEC 60825-1 Ed.3., as described in Laser Notice No. 56, dated May 8, 2019.

The instrument must be used only in combination with the appropriate laser safety box.



Range Measurement Performance

Measuring Principle: echo signal digitization, online waveform processing, time-of-flight measurement, multiple target capability

Laser Power Level Laser Pulse Repetition Rate PRR [1]	100 % 300 kHz	100 % 600 kHz	100 % 1200 kHz	100 % 1800 kHz	100 % 2400 kHz
Max. Measuring Range [2] [3]					
natural targets ρ ≥ 20 %	2980 m	2280 m	1720 m	1450 m	1280 m
natural targets ρ ≥ 60 %	4380 m	3450 m	2670 m	2280 m	2040 m
Max. Operating Flight Altitude [2] [4] Above Ground Level (AGL)					
natural targets ρ ≥ 20 %	2290 m 7550 ft	1760 m 5750 ft	1330 m 4350 ft	1120 m 3650 ft	990 m 3250 ft
natural targets ρ ≥ 60 %	3370 m 11050 ft	2660 m 8700 ft	2060 m 6750 ft	1760 m 5750 ft	1570 m 5150 ft
NOHD [5] [7]	200 m	139 m	95 m	75 m	63 m
ENOHD [6] [7]	1447 m	1016 m	708 m	569 m	486 m
Max. Number of Targets per Pulse [8]	32	24	11	7	5

Laser Power Level Laser Pulse Repetition Rate PRR [1]	75 % 2400 kHz	50 % 2400 kHz	25 % 2400 kHz	12 % 2400 kHz
Max. Measuring Range [2] [3]				
natural targets ρ ≥ 20 %	1130 m	940 m	690 m	490 m
natural targets ρ ≥ 60 %	1810 m	1530 m	1130 m	810 m
Max. Operating Flight Altitude [2] [4] Above Ground Level (AGL)				
natural targets ρ ≥ 20 %	870 m 2850 ft	730 m 2400 ft	530 m 1750 ft	380 m 1250 ft
natural targets ρ ≥ 60 %	1390 m 4550 ft	1180 m 3850 ft	870 m 2850 ft	630 m 2050 ft
NOHD [5] [7]	51 m	39 m	23 m	12 m
ENOHD [6] [7]	411 m	321 m	195 m	111 m
Max. Number of Targets per Pulse [8]	5	5	5	5

1) Rounded average PRR
2) Typical values for average conditions and average ambient brightness. In bright sunlight, the max. range is shorter than under an overcast sky.
3) The maximum range is specified for flat targets with size in excess of the laser beam diameter, perpendicular angle of incidence, and for atmospheric visibility of 23 km. Range ambiguities have to be resolved by multiple-time-around processing.
4) Typical values for max. effective FOV 60°, additional roll angle ± 5°, forward/backward scan angle 20°
5) Nominal Ocular Hazard Distance, based upon MPE according to IEC 60825-1:2014, for single line condition.
6) Extended Nominal Ocular Hazard Distance, based upon MPE according to IEC 60825-1:2014, for single line condition.
7) NOHD and ENOHD have been calculated for a typical angular step width with non-overlapping laser footprints and an aircraft speed higher than 10kn. NOHD and ENOHD increase when using overlapping laser footprints which may be intended e.g. for power line mapping.
8) If more than one target is hit, the total laser transmitter power is split and, accordingly, the achieveable range is reduced.

Minimum Range	20 m
Accuracy [7] [9]	20 mm
Precision [8] [9]	20 mm
Laser Pulse Repetition Rate [10]	up to 2400 kHz
Max. Effective Measurement Rate	up to 2,000,000 meas./sec. (@ 2400 kHz PRR & 60° scan angle)
Echo Signal Intensity	provided for each echo signal
Laser Wavelength	near infrared
Laser Beam Divergence	typ. 0.28 mrad @ $1/e^2$ [11], typ. 0.22 mrad @ 1/e [12]

7) Accuracy is the degree of conformity of a measured quantity to its actual (true) value.
8) Precision, also called reproducibility or repeatability, is the degree to which further measurements show the same result.
9) One sigma @ 150 m range under *RIEGL* test conditions.
10) User selectable.
11) Measured at $1/e^2$ points, 0.28 mrad corresponds to an increase of 28 mm of beam diameter per 100 m distance.
12) Measured at 1/e points, 0.22 mrad corresponds to an increase of 22 mm of beam diameter per 100 m distance.

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Technical Data VQ-680 OEM

Scanner Performance

Scanning Mechanism	rotating polygon mirror
Scan Pattern	parallel scan lines, angular directions -20°, -10°, 0°, +10°, +20° transvers to the scan
Scan Angle Range	± 30° = 60°
Total Scan Rate	50 - 500 lines/sec. [1]
Angular Step Width Δ ϑ	0.008° ≤ Δ ϑ ≤ 0.12° [2] [3]
Angle Measurement Resolution	0.001°

1) The minimum scan rate depends on the selected laser PRR.
2) The angular step width depends on the selected laser PRR.
3) The maximum angular step width is limited by the maximum scan rate.

Data Interfaces

Configuration	LAN 100/1000 MBit/sec
Scan Data Output	LAN 100/1000 MBit/sec
Synchronization	Serial RS-232 interface, TTL input for 1 pps synchronization pulse, accepts different data formats for GNSS-time information

Data Storage

Permanently Installed Data Storage	Solid State Disc SSD, 2 TByte

General Technical Data

Power Supply Input Voltage	18 - 34 V DC
Power Consumption	typ. 100 W, max. 240 W [4]
Main Dimensions (L x W x H)	194 mm x 173 mm x 388 mm (without mounting flange and IMU sensor)
Weight	8.8 kg
Humidity	non condensing
Protection Class	not specified (OEM laser scanner module intended to be integrated into general equipment by professional manufacturers.)
Max. Flight Altitude operating & not operating	18500 ft (5600 m) above MSL (Mean Sea Level)
Temperature Range [5]	-5°C up to +40°C (operation) / -10°C up to +50°C (storage)

4) Max. scan rate, all heaters in operation.
5) To operate the VQ-680 OEM permanently, it is mandatory to ensure that appropriate, forced air cooling is provided to the heat sinks on both sides of the scanner, when considering e.g., an OEM integration into a customized camera system by a third-party company.
Further technical details can be made available on demand.

RIEGL LASER MEASUREMENT SYSTEMS

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