Dual Channel Waveform Processing Airborne LiDAR Scanning System for High Point Density Mapping and Ultra-Wide Area Mapping

NEW

RIEGL VQ®-1560 II-S

- *high laser pulse repetition rate up to 4 MHz*
- *up to 2.66 million measurements per second on the ground*
- *offers highly efficient data acquisition at a wide range of point densities*
- *two waveform processing LiDAR channels offering excellent multiple target detection capability*
- *enables Multiple-Time-Around (MTA) processing of up to 45 pulses simultaneously in the air*
- *excellent suppression of atmospheric clutter*
- *online waveform processing as well as smart and full waveform recording*
- *integrated inertial measurement unit and GNSS receiver*
- *integrated, easily accessible medium format camera*
- *prepared for integration of a secondary camera*
- *high-speed fiber data interface to RIEGL data recorder*
- *housing shape and mounting flange optimized for interfacing with typical hatches and stabilized platforms*
- *detachable handgrips for facilitated handling*

The new VQ-1560II-S follows the successful concept of *RIEGL's* proven dual channel laser scanner series. With increased laser power the operational altitudes are extended up to 1600m AGL at a pulse repetition rate of 4MHz, or up to 4000m AGL at a pulse repetition rate of 540kHz (all values given for 20% target reflectance).
These improved maximum ranges allow an increase of the system's productivity by about 25% for a very attractive point density range. Laser pulse repetition rates can be fine-tuned in 12kHz steps, enabling subtle optimization of acquisition parameters in order to meet specific project requirements.

Its unique "cross-fire" scan pattern and its wide operational range make the instrument the most versatile airborne laser scanner on the market today. It is perfectly suited for any kind of application – from ultra-dense corridor mapping from low altitudes, over high resolution city mapping with minimum shadowing effects in narrow street canyons, to large-scale wide area mapping at utmost efficiency of up to 1130km² per hour at a density of 4 points per square meter.

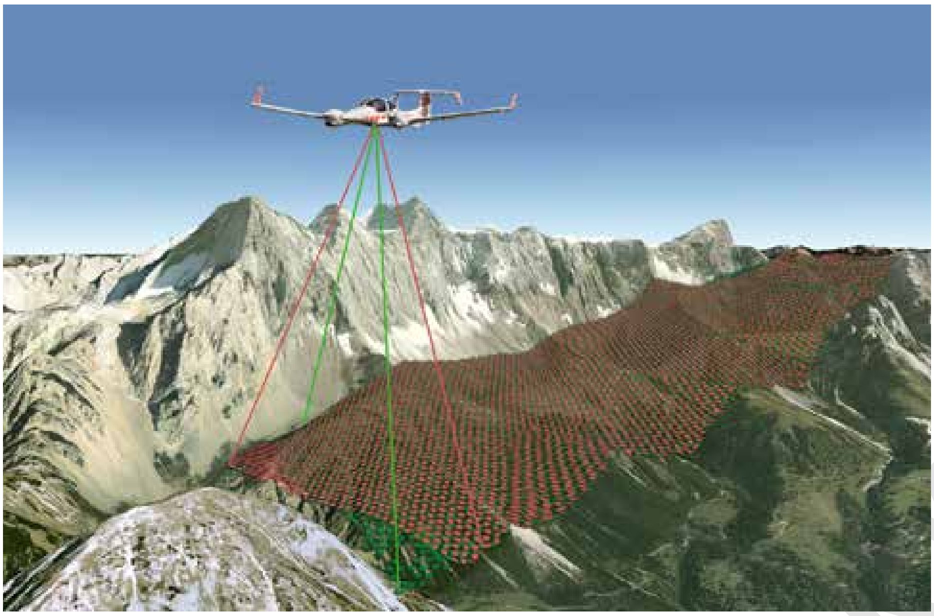
The system is equipped with a seamlessly integrated high performance IMU/GNSS unit and e.g. an optional 150 megapixel RGB camera integrated in the primary camera bay.
Optionally, a second camera, e.g. a thermal camera or a 150 megapixels near-infrared camera, can be integrated on request.
The design of the compact housing features a mounting flange for interfacing with typical hatches or gyro-stabilized leveling mounts.

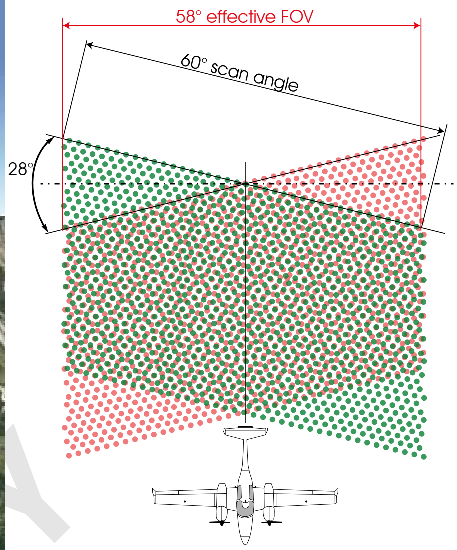
Applications:
- *Ultra Wide Area / High Altitude Mapping*
- *Ultra-High Point Density Mapping*
- *Mapping of Complex Urban Environments*
- *Glacier & Snowfield Mapping*
- *City Modeling*
- *Mapping of Lakesides & River Banks*
- *Agriculture & Forestry*
- *Corridor Mapping*

visit our website
www.riegl.com

RIEGL® LASER MEASUREMENT SYSTEMS

RIEGL VQ-1560 II-S Scan Pattern

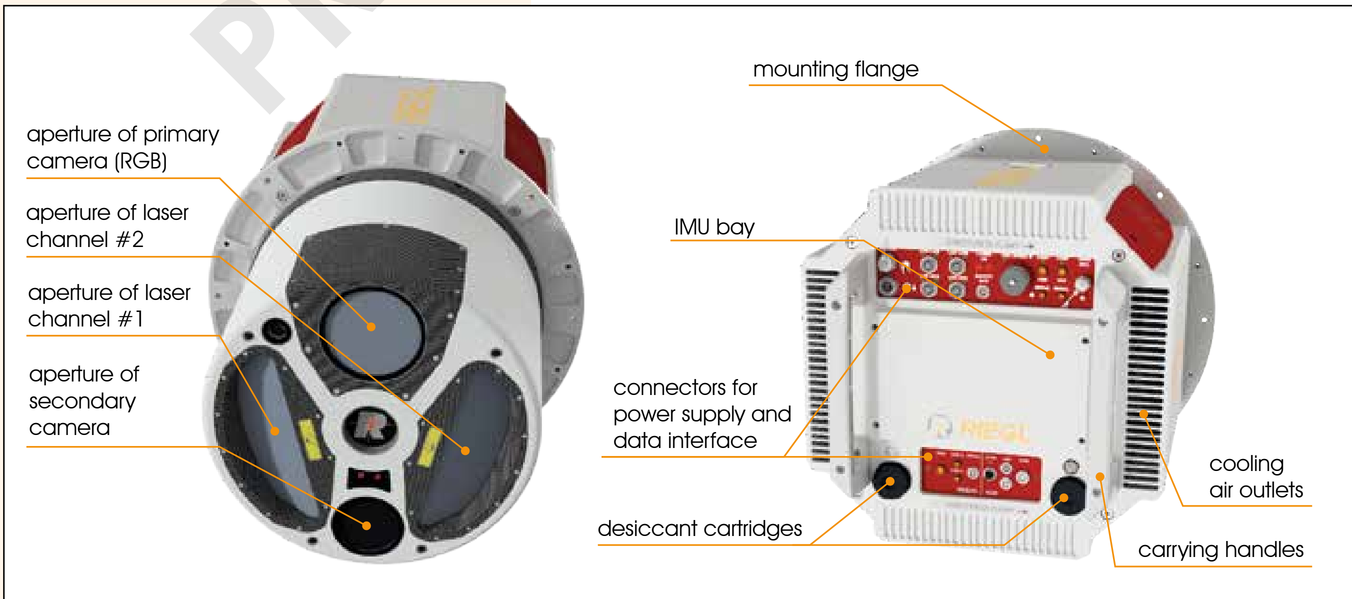




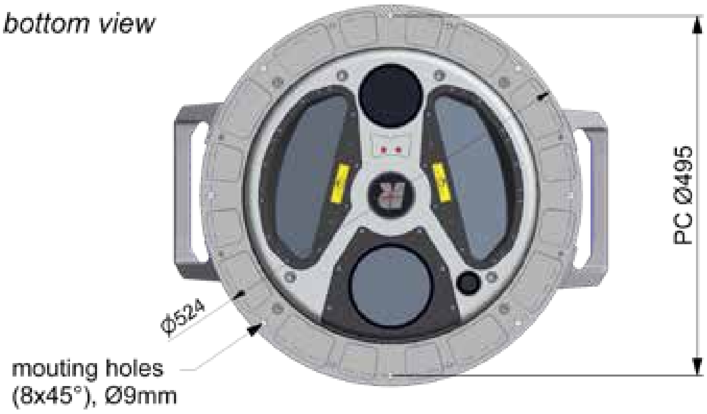
Each channel delivers straight parallel scan lines. The scan lines of the two channels are tilted against each other by 28 degrees providing an optimum distribution of the measurements on the ground invariant to changes in terrain height.

Tilt Angle of Scan Lines	± **14°**
Forward/Backward Scan Angle in Non-Nadir Direction	± **8° at the edge**

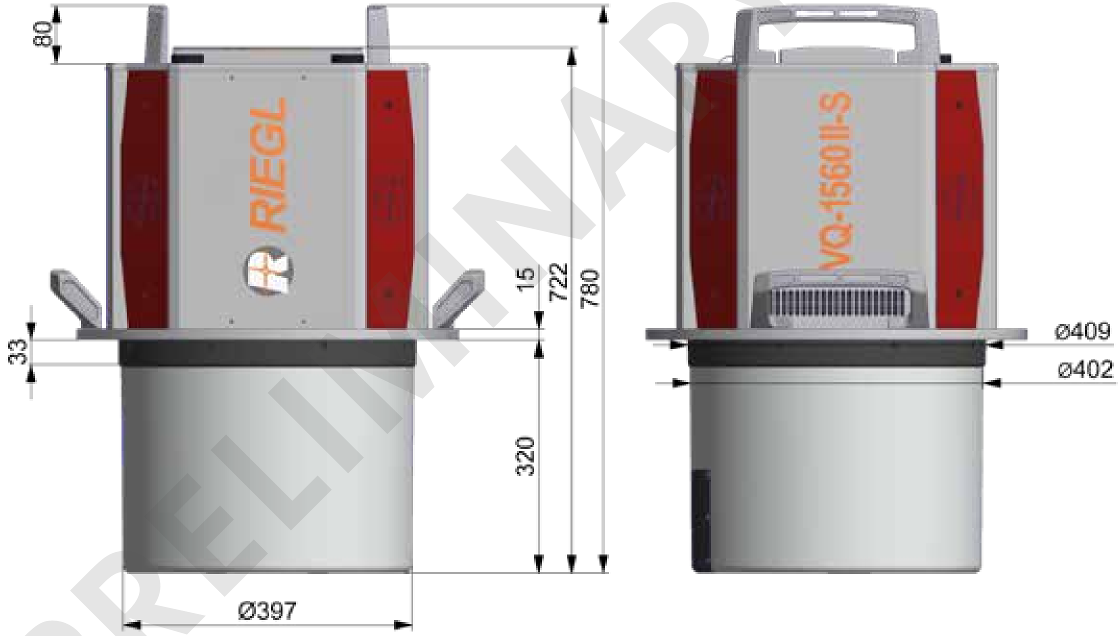
RIEGL VQ-1560 II-S Elements of Function and Operation



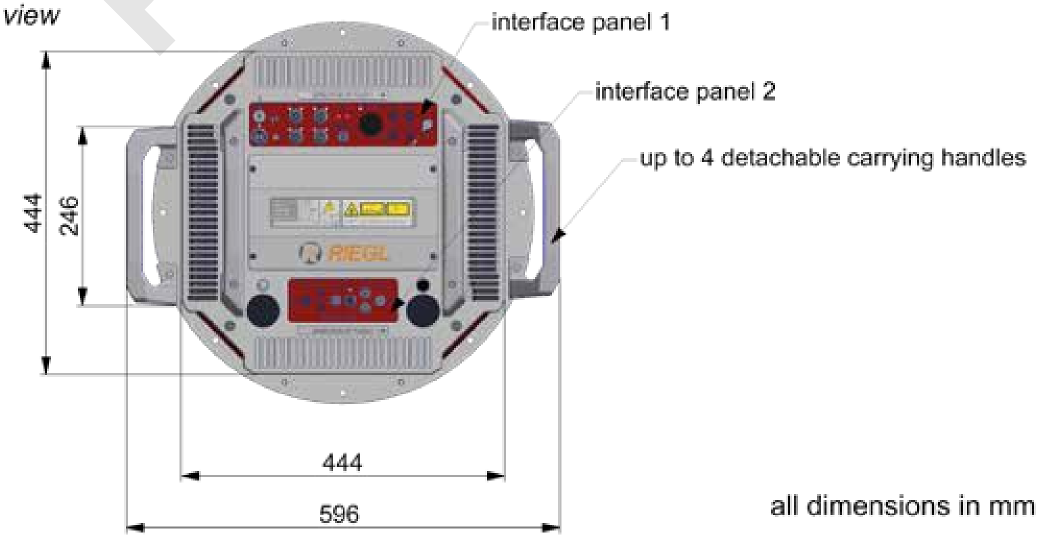
bottom view



side view



top view



all dimensions in mm

RIEGL VQ-1560 II-S System Components

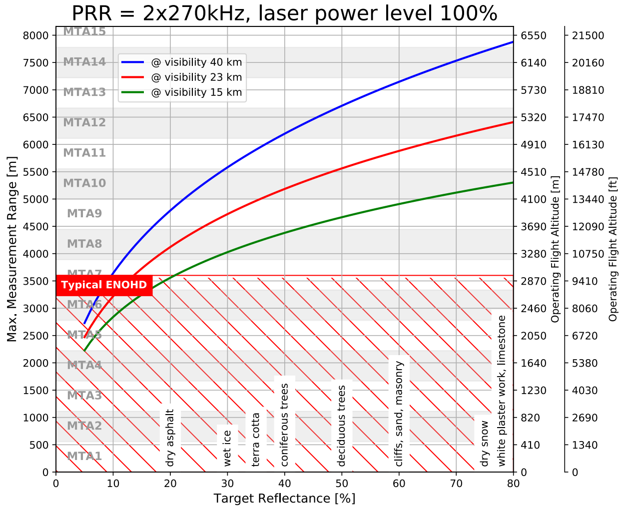
A minimum number of system components and external cabling is required for an easy and quick installation in aircrafts.

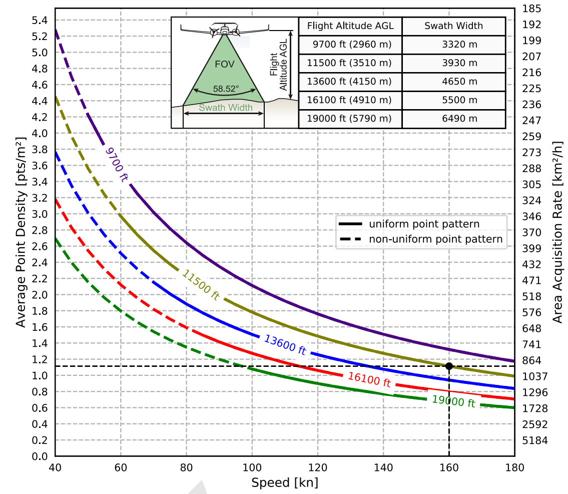
RIEGL VQ-1560 II-S Installation Examples

RIEGL VQ-1560 II-S installed in the nose pod of fixed-wing aircraft DA42 MPP

RIEGL VQ-1560 II-S installed on GSM-4000 gyro-stabilized platform to be used in a helicopter or fixed-wing aircraft

PRR = 2x270kHz, laser power level 100%

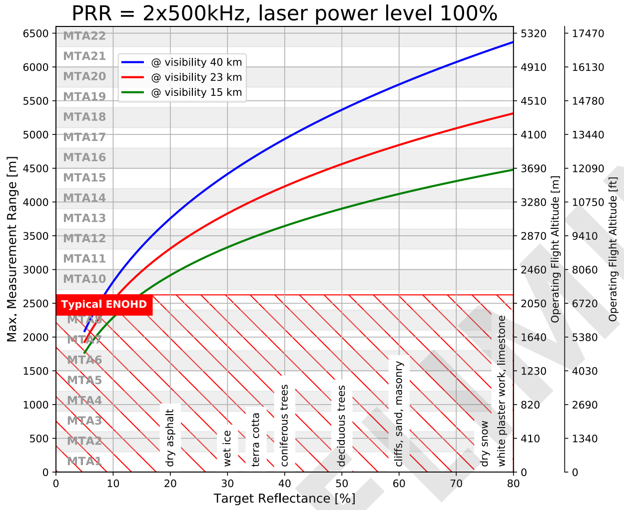


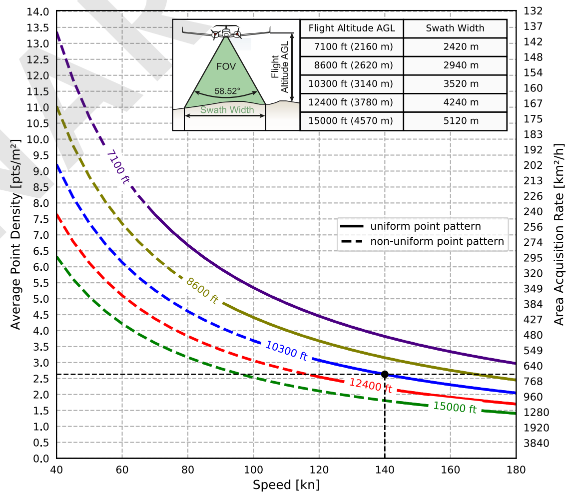


Example: VQ-1560 II-S at 2 x 270,000 pulses/sec, laser power level 100%
Altitude 11,500 ft AGL, Speed 160 kn

Results: Point Density ~ 1.11 pts/m²
Area Acquisition Rate ~ 931 km²/h

PRR = 2x500kHz, laser power level 100%

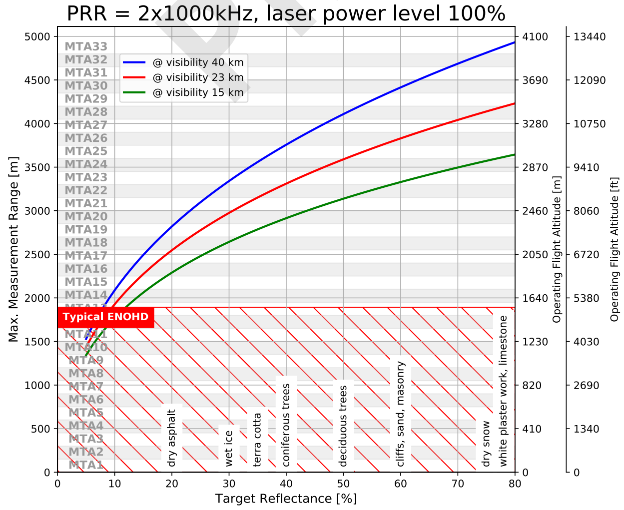


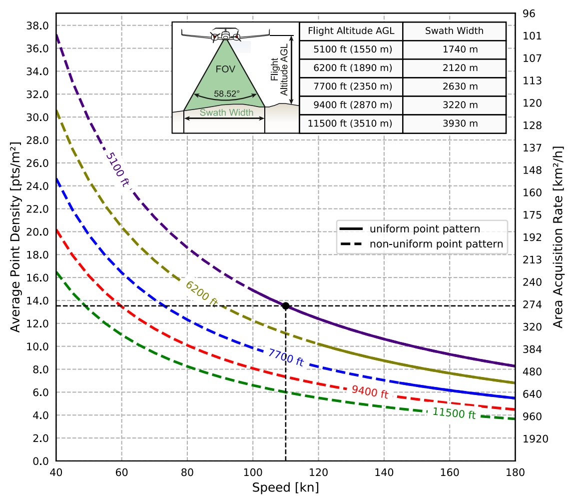


Example: VQ-1560 II-S at 2 x 500,000 pulses/sec, laser power level 100%
Altitude 10,300 ft AGL, Speed 140 kn

Results: Point Density ~ 2.63 pts/m²
Area Acquisition Rate ~ 730 km²/h

PRR = 2x1000kHz, laser power level 100%





Example: VQ-1560 II-S at 2 x 1,000,000 pulses/sec, laser power level 100%
Altitude 5,100 ft AGL, Speed 110 kn

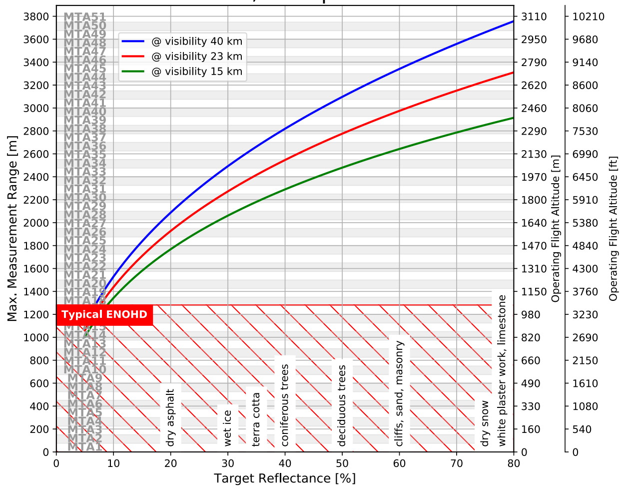
Results: Point Density ~ 13.53 pts/m²
Area Acquisition Rate ~ 284 km²/h

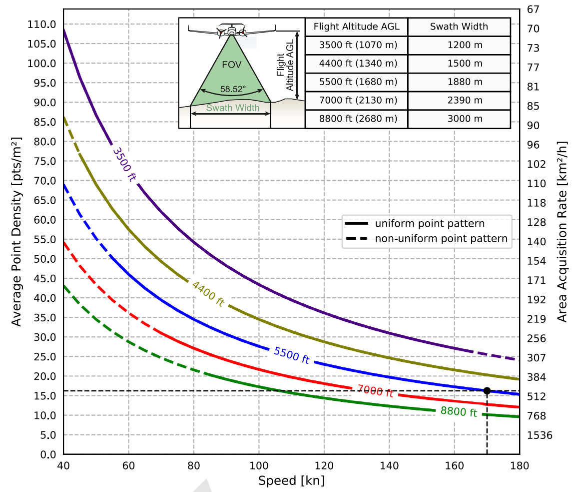
The following conditions are assumed for the Operating Flight Altitude AGL
- ambiguity resolved by multiple-time-around (MTA) processing
- target size ≥ laser footprint
- effective FOV 58°
- average ambient brightness
- roll angle ±5°

Assumptions for calculation of the Area Acquisition Rate
- 20% overlap of neighboring flight strips. This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

Typical ENOHD
- Calculated under assumption of an angular step width of 0.012° and an aircraft speed higher than 10kn.

PRR = 2x2000kHz, laser power level 100%

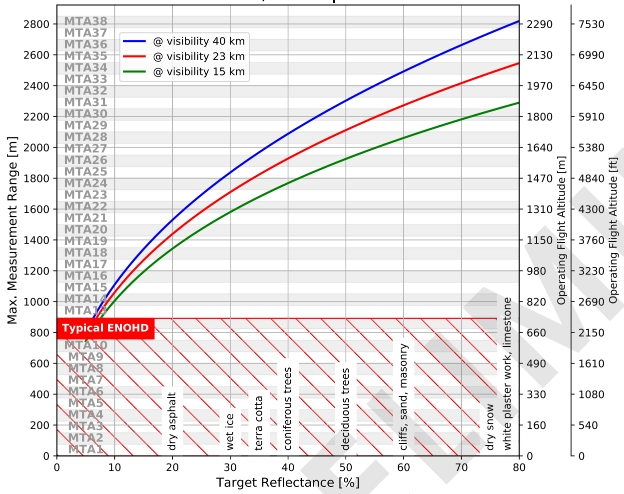


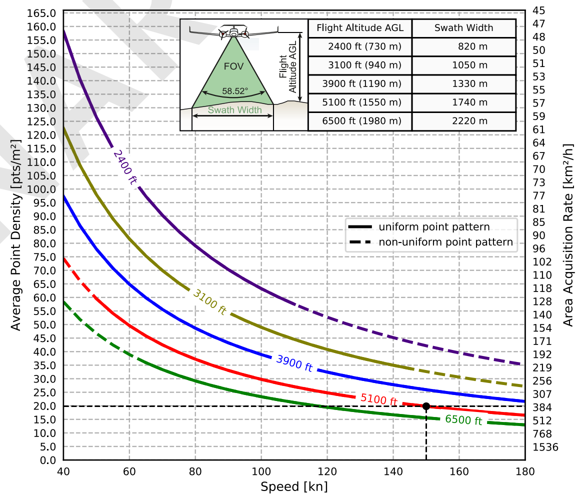


Example: VQ-1560 II-S at 2 x 2,000,000 pulses/sec, laser power level 100%
Altitude 5,500 ft AGL, Speed 170 kn

Results: Point Density ~ 16.23 pts/m²
Area Acquisition Rate ~ 473 km²/h

PRR = 2x2000kHz, laser power level 50%

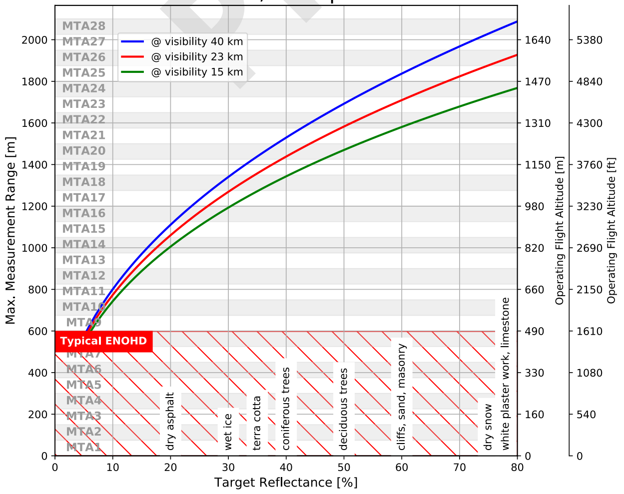


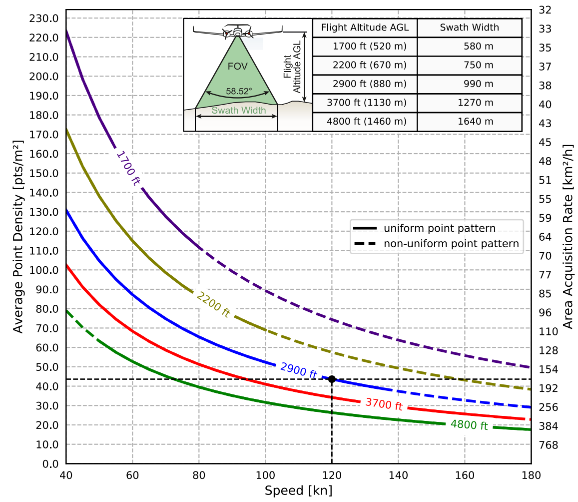


Example: VQ-1560 II-S at 2 x 2,000,000 pulses/sec, laser power level 50%
Altitude 5,100 ft AGL, Speed 150 kn

Results: Point Density ~ 19.84 pts/m²
Area Acquisition Rate ~ 387 km²/h

PRR = 2x2000kHz, laser power level 25%





Example: VQ-1560 II-S at 2 x 2,000,000 pulses/sec, laser power level 25%
Altitude 2,900 ft AGL, Speed 120 kn

Results: Point Density ~ 43.62 pts/m²
Area Acquisition Rate ~ 176 km²/h

The following conditions are assumed for the Operating Flight Altitude AGL

- ambiguity resolved by multiple-time-around (MTA) processing
- target size ≥ laser footprint
- average ambient brightness
- effective FOV 58°
- roll angle ±5°

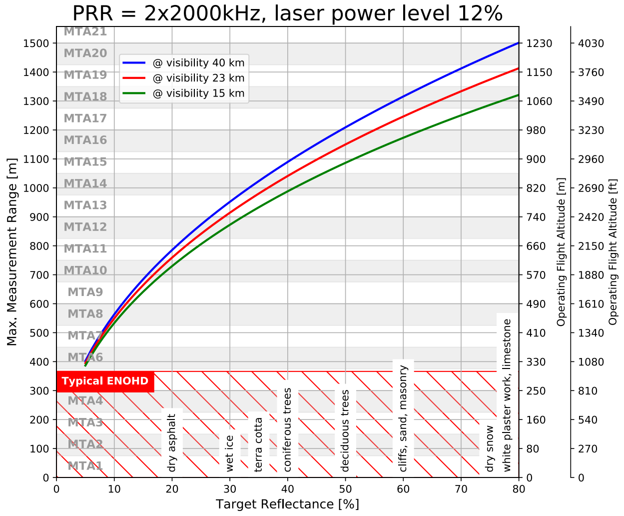
Assumptions for calculation of the Area Acquisition Rate

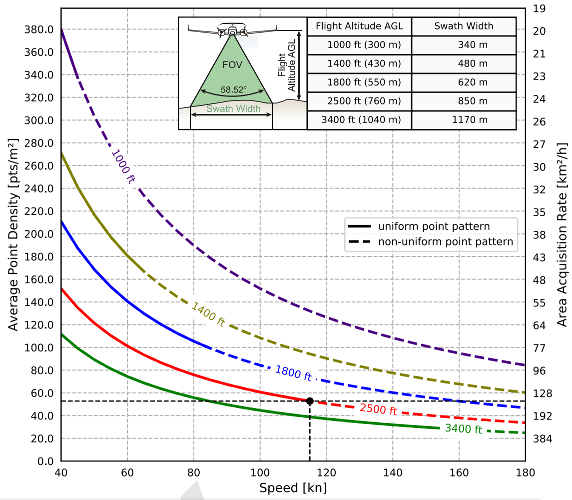
- 20% overlap of neighboring flight strips. This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

Typical ENOHD

- Calculated under assumption of an angular step width of 0.012° and an aircraft speed higher than 10kn.

PRR = 2x2000kHz, laser power level 12%

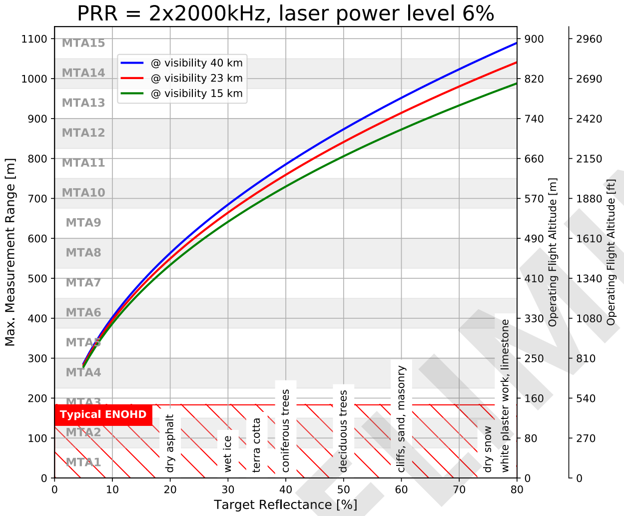


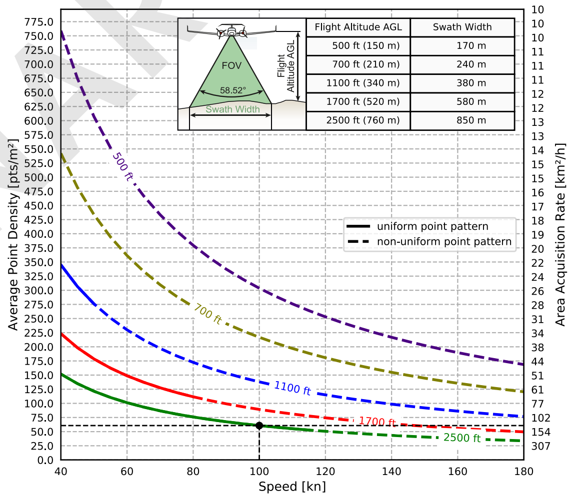


Example: VQ-1560 II-S at 2 x 2,000,000 pulses/sec, laser power level 12%
Altitude 2,500 ft AGL, Speed 115 kn

Results: Point Density ~ 52.8 pts/m²
Area Acquisition Rate ~ 145 km²/h

PRR = 2x2000kHz, laser power level 6%





Example: VQ-1560 II-S at 2 x 2,000,000 pulses/sec, laser power level 6%
Altitude 2,500 ft AGL, Speed 100 kn

Results: Point Density ~ 60.72 pts/m²
Area Acquisition Rate ~ 126 km²/h

The following conditions are assumed for the Operating Flight Altitude AGL

- ambiguity resolved by multiple-time-around (MTA) processing
- target size ≥ laser footprint
- effective FOV 58°
- average ambient brightness
- roll angle ±5°

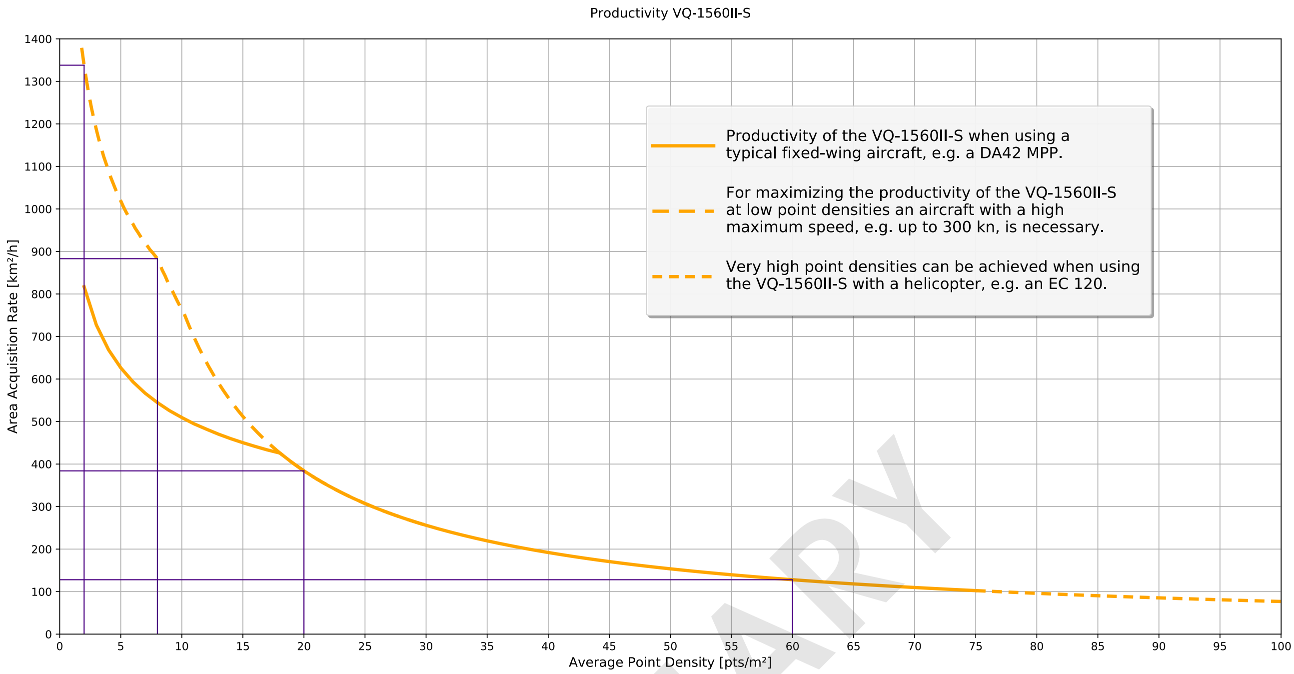
Assumptions for calculation of the Area Acquisition Rate

- 20% overlap of neighboring flight strips. This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

Typical ENOHD

- Calculated under assumption of an angular step width of 0.012° and an aircraft speed higher than 10kn.

The *RIEGL* VQ-1560 II-S Dual Channel Airborne Mapping System offers highest productivity.



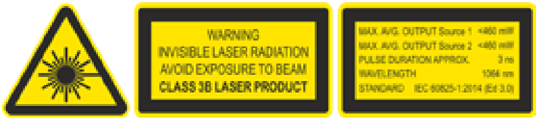
Examples [1]				
Average Point Density	2 pts/m²	8 pts/m²	20 pts/m²	60 pts/m²
Flight Altitude	8100 ft 2690 m	5820 ft 1770 m	3990 ft 1220 m	2490 ft 760 m
Ground Speed	300 kn	300 kn	190 kn	101 kn
Swath Width	3010 m	1990 m	1360 m	850 m
Productivity	1338 km²/h	883 km²/h	384 km²/h	128 km²/h
Measurement Rate [2]	929 000 meas./sec	2.45 mill meas./sec	2.66 mill meas./sec	2.66 mill meas./sec
Camera GSD [3] [4]	201 mm	133 mm	91 mm	57 mm
Camera Trigger Intervall [4]	5.6 sec	3.7 sec	4.0 sec	4.7 sec

1) calculated for 20% target reflectivity and 20% stripe overlap
2) The target detection rate is equal to the measurement rate for terrains offering only one target per laser pulse but may be much higher for vegetated areas.
3) Ground Sampling Distance
4) Calculated for a 150 MPixel CMOS camera with a FOV of 56.2° x 43.7° and 60% image overlap in flight direction (endlap).

Laser Product Classification

Class 3B Laser Product according to IEC60825-1:2014

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

as a function of laser power setting, PRR, and target reflectivity

Laser Power Level	100%			
Laser Pulse Repetition Rate (PRR) [1]	2 x 270 kHz	2 x 500 kHz	2 x 1000 kHz	2 x 2000 kHz
Max. Measuring Range [2) 3) 4)]				
natural targets ρ ≥ 20 %	4800 m	3700 m	2800 m	2050 m
natural targets ρ ≥ 60 %	7100 m	5600 m	4300 m	3300 m
Max. Operating Flight Altitude [2) 5)] (AGL) [6)]				
natural targets ρ ≥ 20 %	3900 m 12800 ft	3000 m 10000 ft	2200 m 7500 ft	1700 m 5500 ft
natural targets ρ ≥ 60 %	5800 m 19000 ft	4600 m 15000 ft	3500 m 11500 ft	2700 m 8800 ft
NOHD [7) 9)]	430 m	310 m	220 m	155 m
ENOHD [8) 9)]	2950 m	2150 m	1550 m	1050 m
Number of Targets per Laser Pulse up to [10)]	14	14	9	4

Laser Power Level	50%	25%	12%	6%
Laser Pulse Repetition Rate (PRR) [1)]	2 x 2000 kHz	2 x 2000 kHz	2 x 2000 kHz	2 x 2000 kHz
Max. Measuring Range [2) 3) 4)]				
natural targets ρ ≥ 20 %	1500 m	1100 m	780 m	560 m
natural targets ρ ≥ 60 %	2450 m	1800 m	1300 m	940 m
Max. Operating Flight Altitude [2) 5)] (AGL) [6)]				
natural targets ρ ≥ 20 %	1200 m 4100 ft	900 m 2900 ft	630 m 2100 ft	450 m 1500 ft
natural targets ρ ≥ 60 %	2000 m 6500 ft	1450 m 4800 ft	1050 m 3400 ft	760 m 2500 ft
NOHD [7) 9)]	105 m	67 m	38 m	22 m
ENOHD [8) 9)]	730 m	490 m	300 m	150 m
Number of Targets per Laser Pulse up to [10)]	4	4	4	4

1) rounded average PRR
2) Typical values for average conditions and average ambient brightness; in bright sunlight the operational range may be considerably shorter and the operational flight altitude may be considerably lower 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 40 km. Range ambiguities have to be resolved by multiple-time-around processing.
4) If the laser beam hits, in part, more than one target, the laser's pulse power is split accordingly. Thus, the achievable range is reduced.
5) Typical values for max. effective FOV 58°, additional roll angle ± 5°
6) Above Ground Level
7) Nominal Ocular Hazard Distance, based upon MPE according to IEC 60825-1:2014, for single line condition
8) Extended Nominal Ocular Hazard Distance, based upon MPE according to IEC 60825-1:2014, for single line condition
9) NOHD and ENOHD have been calculated for a typical angular step width of 0.012° (which means non-overlapping laser footprints), and an aircraft speed higher than 10 kn. NOHD and ENOHD increase when using overlapping laser footprints which may be intended e.g. for power line mapping.
10) when using online waveform processing

Minimum Range [11)]	100 m
Accuracy [12) 13)] / Precision [13) 14)]	20 mm / 20 mm
Laser Pulse Repetition Rate [15)]	2 x 270kHz up to 2 x 2000kHz, selectable in steps of less than 1%
Effective Measurement Rate	up to 2 x 1.33 MHz @ 60° scan angle
Echo Signal Intensity	provided for each echo signal
Laser Wavelength	near infrared
Laser Beam Divergence	typ. 0.17 mrad @ 1/e [16)], typ. 0.23 mrad @ $1/e^2$ [17)]

Scanner Performance

Scanning Mechanism	rotating polygon mirror
Scan Pattern	parallel scan lines per channel, crossed scan lines between channels
Tilt Angle of Scan Lines	± 14° = 28°
Forward/ Backward Scan Angle in Non-Nadir Direction	± 8° at the edges
Scan Angle Range	60° total per channel, resulting in an effective FOV of 58°
Total Scan Rate	40 [18)] - 600 lines/sec
Angular Step Width Δϑ	0.006° ≤ Δϑ ≤ 0.100° [19) 20)]
Angle Measurement Resolution	0.001°

11) Limitation for range measurement capability, does not consider laser safety issues! The minimum range for valid reflectivity values is 250 m.
12) Accuracy is the degree of conformity of a measured quantity to its actual (true) value.
13) Standard deviation one sigma @ 250 m range under *RIEGL* test conditions.
14) Precision, also called reproducibility or repeatability, is the degree to which further measurements show the same result.
15) For smart and full waveform recording the max. laser PRR is limited to 2 x 1600kHz.
16) Measured at the 1/e points. 0.17 mrad correspond to an increase of 17 cm of beam diameter per 1000 m distance.
17) Measured at the $1/e^2$ points. 0.23 mrad correspond to an increase of 23 cm of beam diameter per 1000 m distance.
18) The minimum scan rate depends on the selected laser PRR.
19) The minimum angular step width depends on the selected laser PRR.
20) The maximum angular step width is limited by the maximum scan rate.

Technical Data to be continued at page 10

Data Interfaces

Configuration	TCP/IP Ethernet (10/100/1000 MBit/s)
Monitoring Data Output	TCP/IP Ethernet (10/100/1000 MBit/s)
Digitized Data Output	Dual glass fiber data link to *RIEGL* Data Recorder DR1560i
Synchronization	Serial RS-232 interface, TTL input for 1 pps synchronization pulse, accepts different data formats for GNSS-time information

General Technical Data

Power Supply / Power Consumption	20 - 32 V DC / typ. 370 W max. 550 W, depending on integrated optional components
Main Dimensions (flange diameter x height)	Ø 524 mm x 780 mm (without flange mounted carrying handles)
Weight	approx. 55 kg without any camera but including a typical IMU/GNSS unit approx. 60 kg with optional components
Protection Class	IP54
Max. Flight Altitude operating / not operating	18500 ft (5600 m) above MSL[1] / 18500 ft (5600 m) above MSL
Temperature Range operation / storage	-5°C up to +35°C / -10°C up to +50°C

1) Mean Sea Level

Recommended IMU/GNSS System [2) 3)]

IMU Accuracy [4)]	
Roll, Pitch	0.0025°
Heading	0.005°
IMU Sampling Rate	200 Hz
Position Accuracy (typ.)	0.05 m - 0.1 m

Optional Components VQ-1560II-S

Primary Camera	RGB
Sensor Resolution	e.g. 150 MPixel CMOS
Sensor Dimensions (diagonal)	66.7 mm (medium format)
Focal Length of Camera Lens	50 mm
Field of View (FOV)	approx. 54.6° x 42.3°
Interface	USB 3.0
Data Storage	iX-Controller
Secondary Camera	Different camera types including thermal or NIR cameras can be integrated, details on request.

2) The recommended IMU is listed neither in the European Export Control List (i.e. Annex 1 of Council Regulation 428/2009) nor in the Canadian Export Control List. Detailed information on certain cases will be provided on request.
3) The *RIEGL* VQ-1560 II-S Laser Scanning system supports different IMU/GNSS Systems, details on request.

4) One sigma values, no GNSS outages, post-processed with base station data

RIEGL LASER MEASUREMENT SYSTEMS

RIEGL
Laser Measurement Systems GmbH
Riedenburgstraße 48
3580 Horn, Austria
Phone: +43 2982 4211
office@riegl.co.at | www.riegl.com

RIEGL USA Inc. | info@rieglusa.com | www.rieglusa.com
RIEGL Japan Ltd. | info@riegl-japan.co.jp | www.riegl-japan.co.jp
RIEGL China Ltd. | info@riegl.cn | www.riegl.cn
RIEGL Australia Pty Ltd. | info@riegl.com.au | www.riegl.com

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