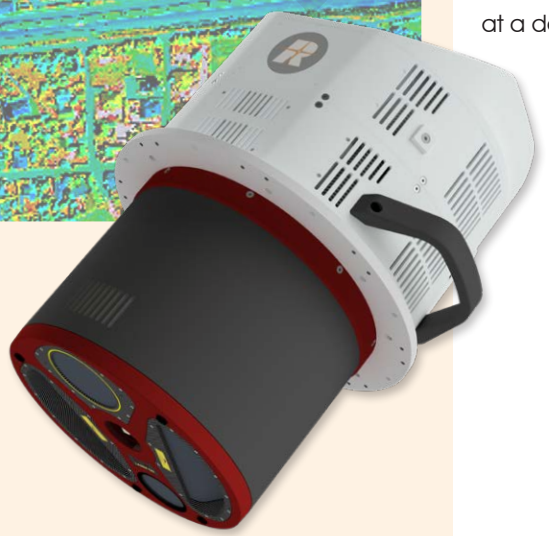
Dual Channel Waveform Processing Airborne LiDAR Scanning System for High Point Density Mapping and Ultra-Wide Area Mapping

NEW

RIEGL VQ®-1560 III-S

- *high pulse repetition rates of up to 4.4 MHz*
- *up to 2.93 million measurements per second on the ground*
- *best point distribution for optimum target sampling*
- *atmospheric clutter suppression*
- *multiple target capability*
- *online waveform processing and full waveform data recording*
- *increased sample block lengths*
- *on-board graphical user interface for easy access to primary scanner parameters*
- *integrated inertial measurement unit and GNSS receiver*
- *prepared for the integration of up to two high resolution RGB/NIR cameras*
- *optimized for interfacing with typical hatches and stabilized platforms*
- *detachable handgrips for facilitated handling*



The VQ-1560III-S is the latest successor in the proven *RIEGL* dual channel laser scanning system series, suitable for a wide field of applications – from high-point density wide area mapping to ultra-high resolution city mapping or corridor mapping.

The well-established "cross-fire" scan pattern – with two scan lines rotated against each other – enables a forward and backward view to the edges of the swath and a nadir view in the middle of the swath.
High pulse repetition rates of up to 4.4 MHz enable operational flying altitudes of up to 1,600 m AGL, or up to 3,900 m AGL at a pulse repetition rate of 560 kHz (all values given for 20% target reflectance). Laser pulse repetition rates can be fine-tuned in 12-kHz-steps, which enables subtle optimization of acquisition parameters in order to meet specific project requirements.

Online-waveform processing and full-waveform processing capabilities are standard methods for target detection. Scan data and camera images are stored on removable hard disks that can be accessed directly on the device, eliminating the need for an external data recorder. A high-performance IMU/GNSS unit and one or two optional high resolution RGB/NIR cameras are seamlessly integrated in the compact and user-friendly designed housing. The standardized mounting flange fits typical hatches or gyro-stabilized leveling mounts for maintaining optimum point distribution.

Both, the scan pattern and its wide operational range make the instrument one of 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 1,130 km² per hour at a density of 4 points per square meter.

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*

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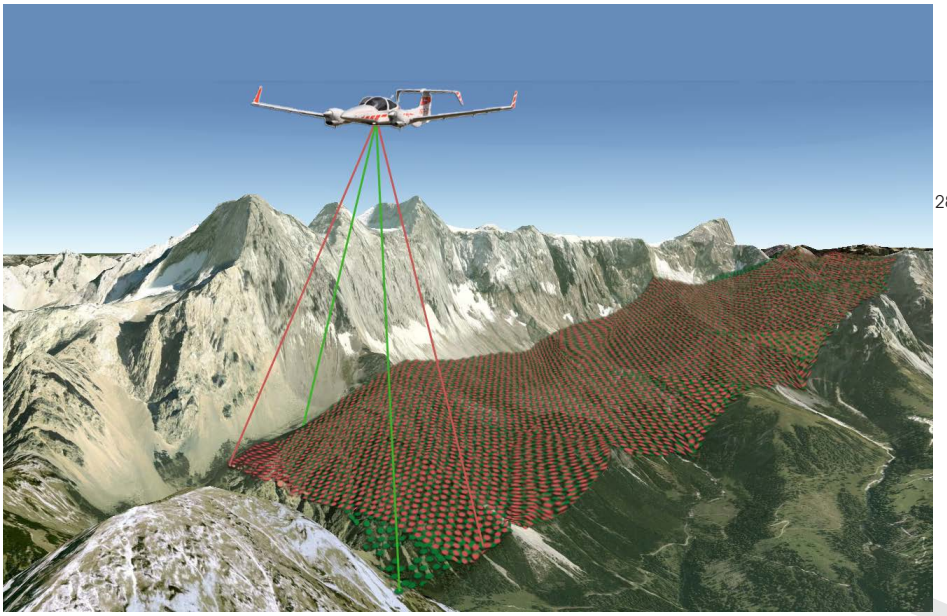
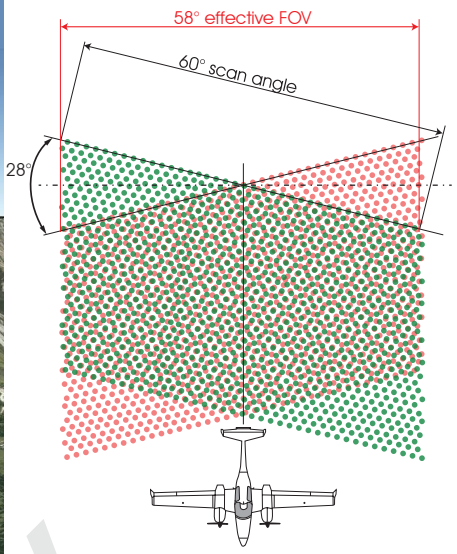
www.riegl.com

RIEGL®
LASER MEASUREMENT SYSTEMS

RIEGL VQ-1560 III-S Dense Scan Pattern and Wide Effective Swath Width

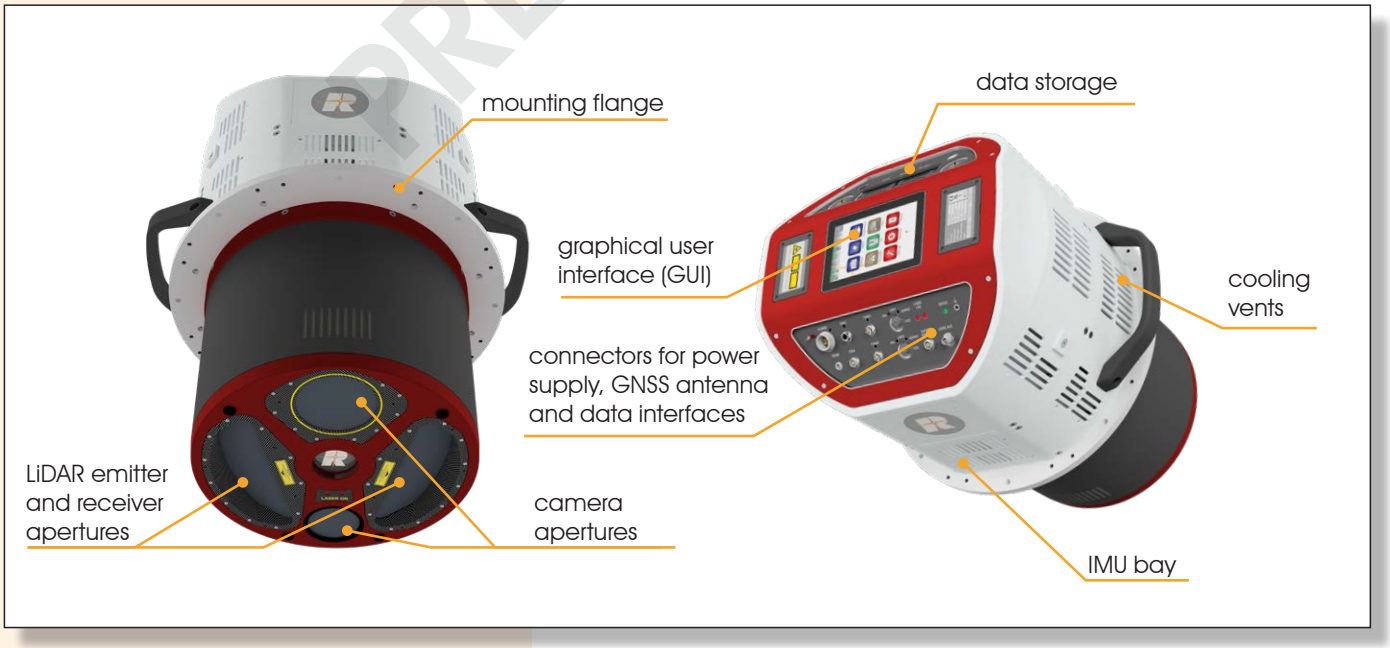




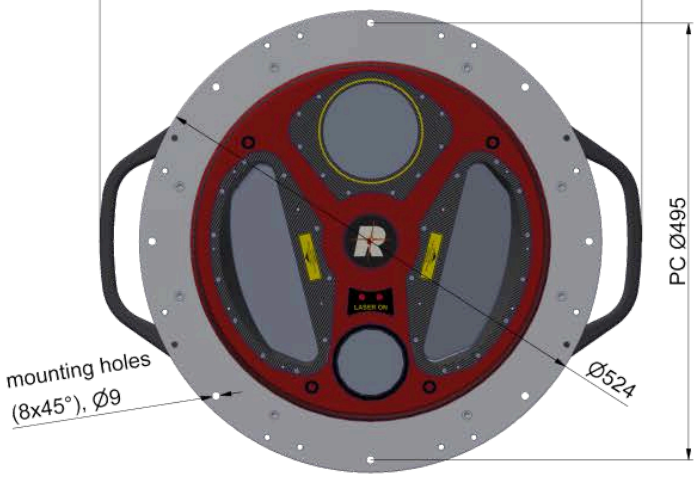
Each channel delivers straight parallel scan lines. The scan lines of the two channels are tilted against each other by 28 degrees providing an optimum distribution of the measurements on the ground invariant to changes in terrain height.

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

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

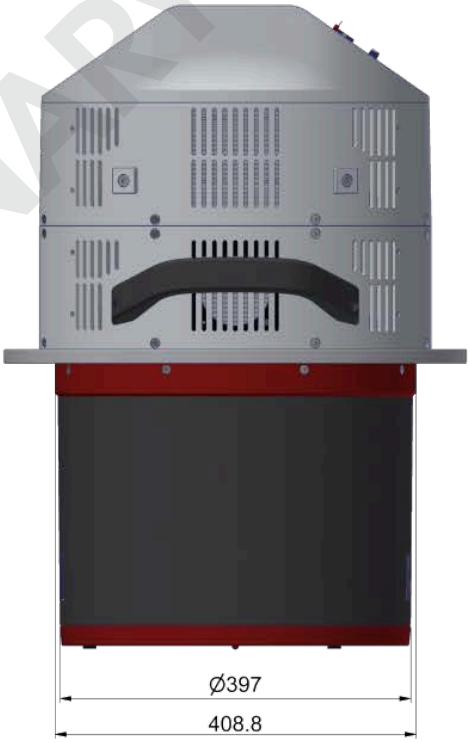


Bottom View

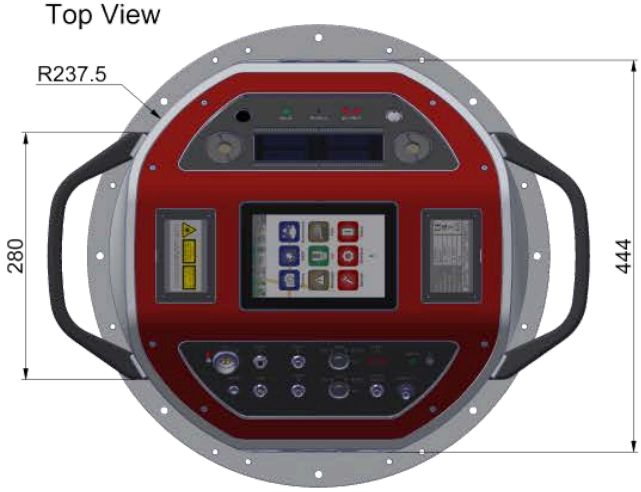


Side View

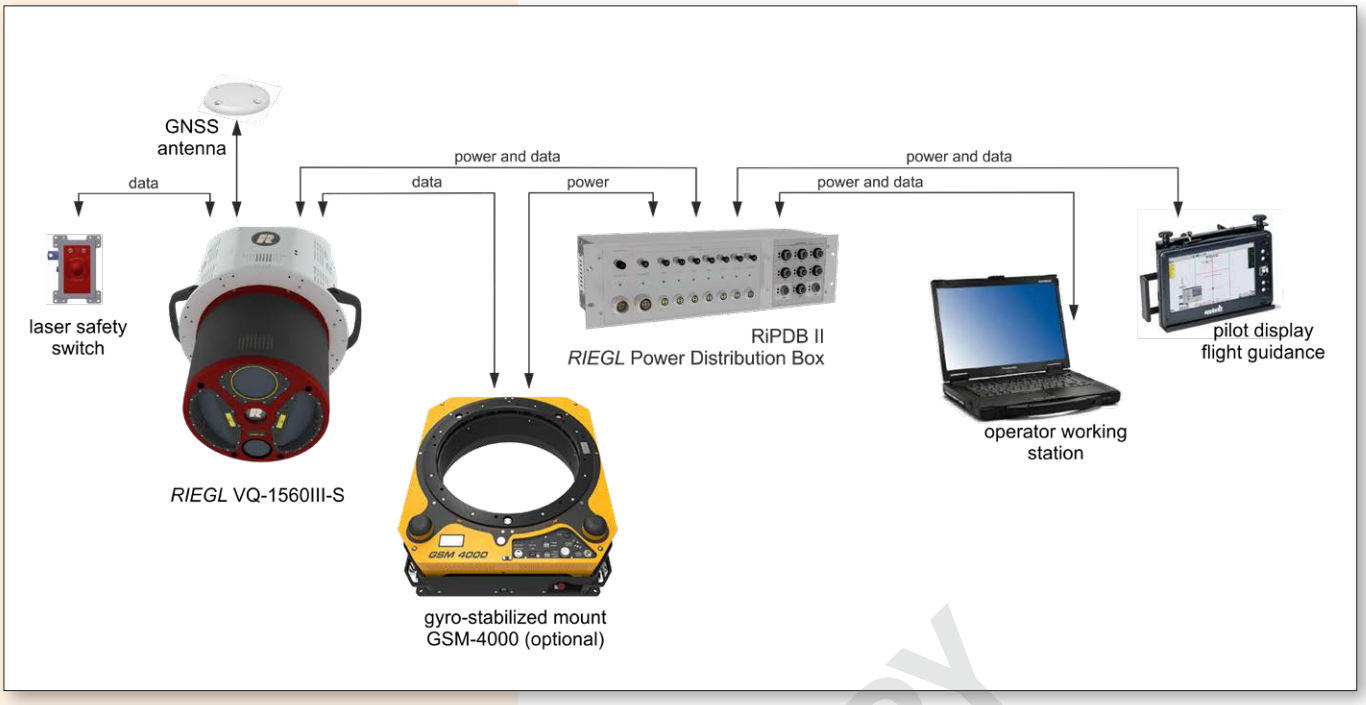
Side View



Top View



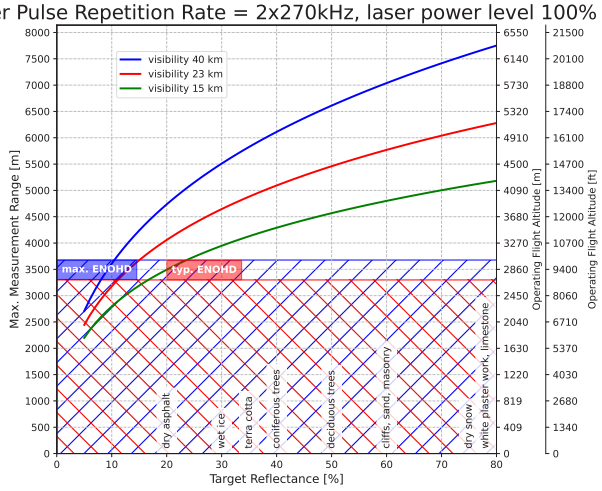
dimensions in mm

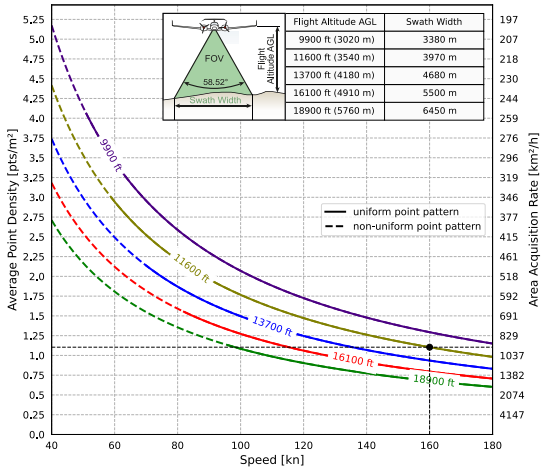


A minimum number of system components and external cabling is required for an easy and quick installation in aircrafts.

RIEGL VQ-1560 III-S installed in Diamond Aircraft DA62 Survey Star

Laser Pulse Repetition Rate = 2x270kHz, laser power level 100%

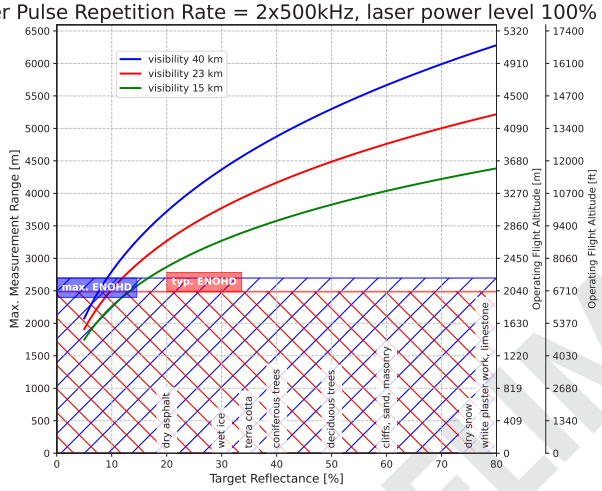


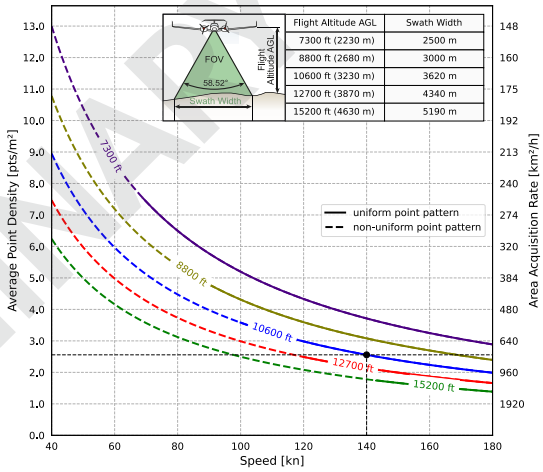


Example: VQ-1560 III-S at 2 x 270,000 pulses/sec, laser power level 100%
Altitude 11,600 ft AGL, Speed 160 kn

Results: Point Density ~ 1.1 pts/m²
Area Acquisition Rate ~ 939 km²/h

Laser Pulse Repetition Rate = 2x500kHz, laser power level 100%

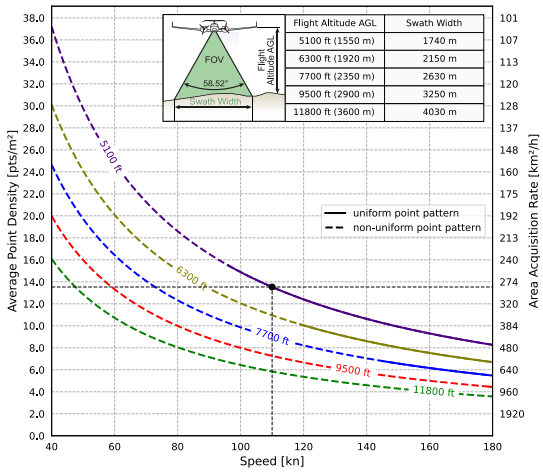




Example: VQ-1560 III-S at 2 x 500,000 pulses/sec, laser power level 100%
Altitude 10,600 ft AGL, Speed 140 kn

Results: Point Density ~ 2.56 pts/m²
Area Acquisition Rate ~ 751 km²/h

Laser Pulse Repetition Rate = 2x1000kHz, laser power level 100%



Example: VQ-1560 III-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°

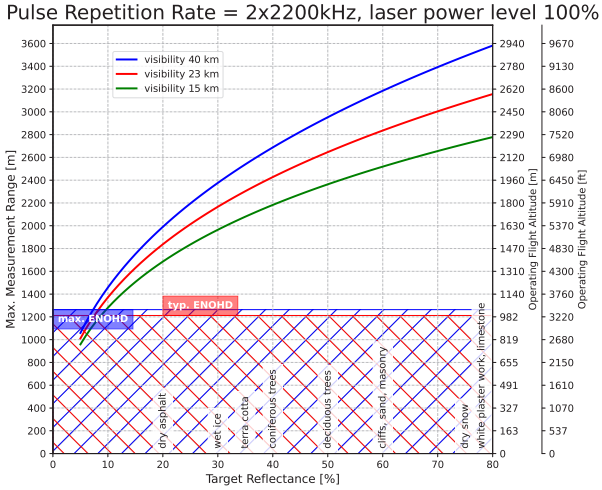
Assumptions for calculation of the Area Acquisition Rate

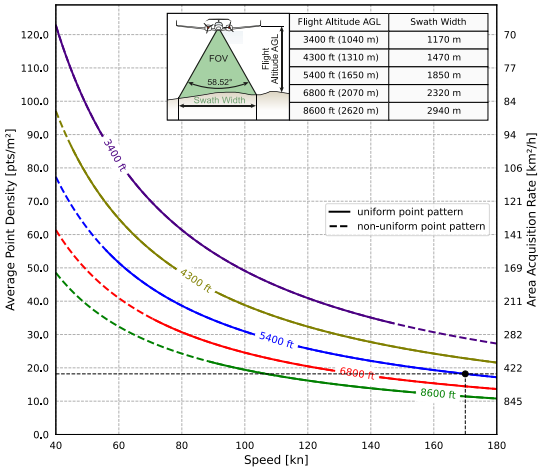
- 20% overlap of neighboring flight strips. This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

Typical ENOHD

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

Laser Pulse Repetition Rate = 2x2200kHz, laser power level 100%

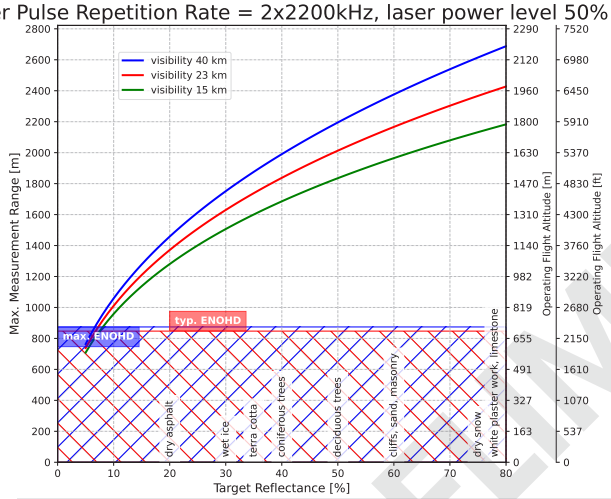


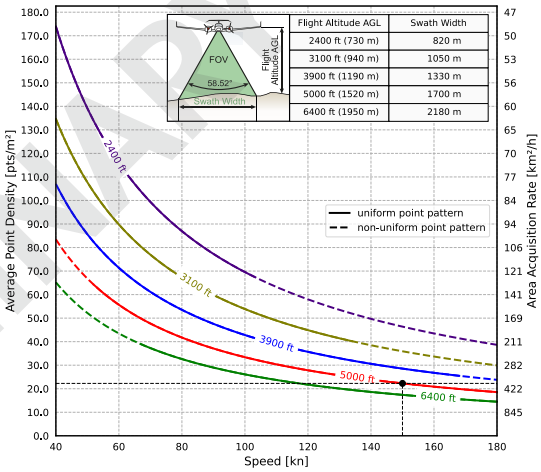


Example: VQ-1560 III-S at 2 x 2,200,000 pulses/sec, laser power level 100%
Altitude 5,400 ft AGL, Speed 170 kn

Results: Point Density ~ 18.19 pts/m²
Area Acquisition Rate ~ 464 km²/h

Laser Pulse Repetition Rate = 2x2200kHz, laser power level 50%

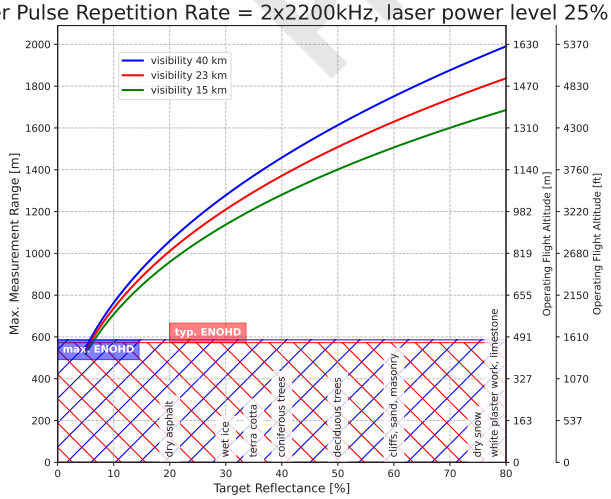


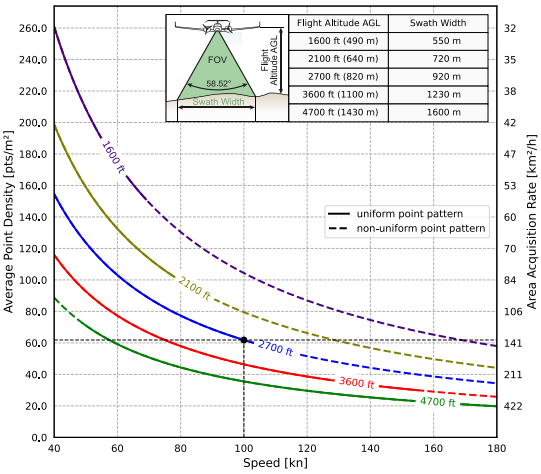


Example: VQ-1560 III-S at 2 x 2,200,000 pulses/sec, laser power level 50%
Altitude 5,000 ft AGL, Speed 150 kn

Results: Point Density ~ 22.26 pts/m²
Area Acquisition Rate ~ 379 km²/h

Laser Pulse Repetition Rate = 2x2200kHz, laser power level 25%





Example: VQ-1560 III-S at 2 x 2,200,000 pulses/sec, laser power level 25%
Altitude 2,700 ft AGL, Speed 100 kn

Results: Point Density ~ 61.84 pts/m²
Area Acquisition Rate ~ 137 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°

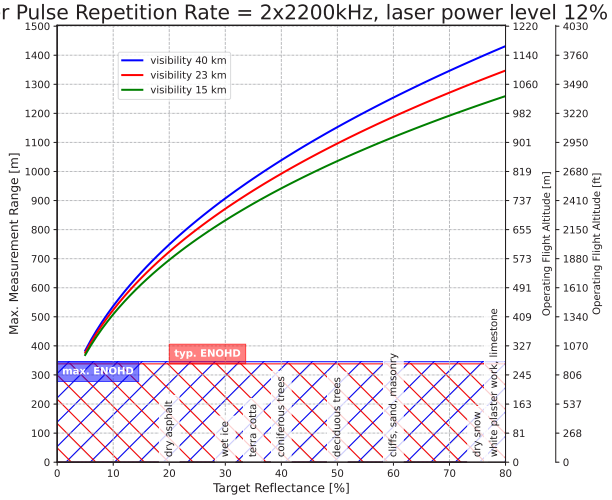
Assumptions for calculation of the Area Acquisition Rate

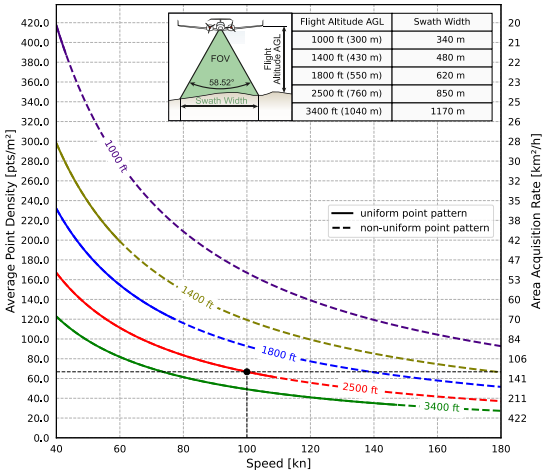
- 20% overlap of neighboring flight strips. This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

Typical ENOHD

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

Laser Pulse Repetition Rate = 2x2200kHz, laser power level 12%

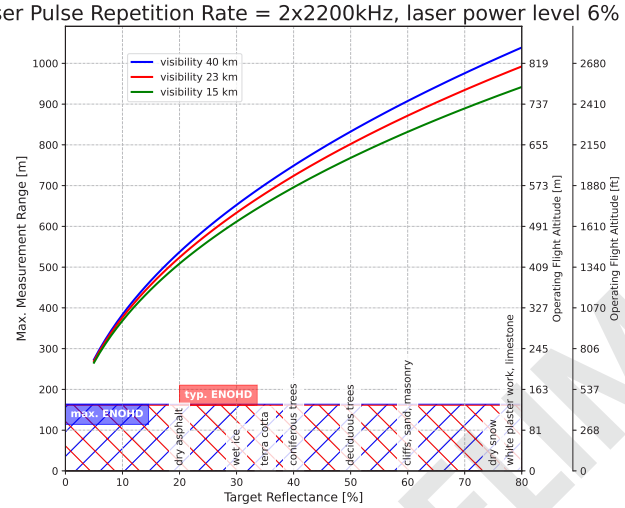


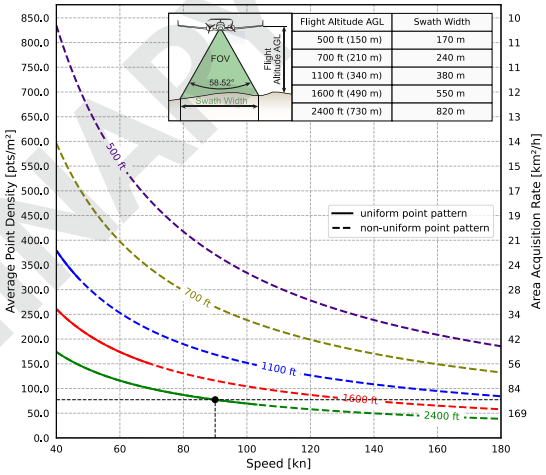


Example: VQ-1560 III-S at 2 x 2,200,000 pulses/sec, laser power level 12%
Altitude 2,500 ft AGL, Speed 100 kn

Results: Point Density ~ 66.79 pts/m²
Area Acquisition Rate ~ 126 km²/h

Laser Pulse Repetition Rate = 2x2200kHz, laser power level 6%





Example: VQ-1560 III-S at 2 x 2,200,000 pulses/sec, laser power level 6%
Altitude 2,400 ft AGL, Speed 90 kn

Results: Point Density ~ 77.3 pts/m²
Area Acquisition Rate ~ 109 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°

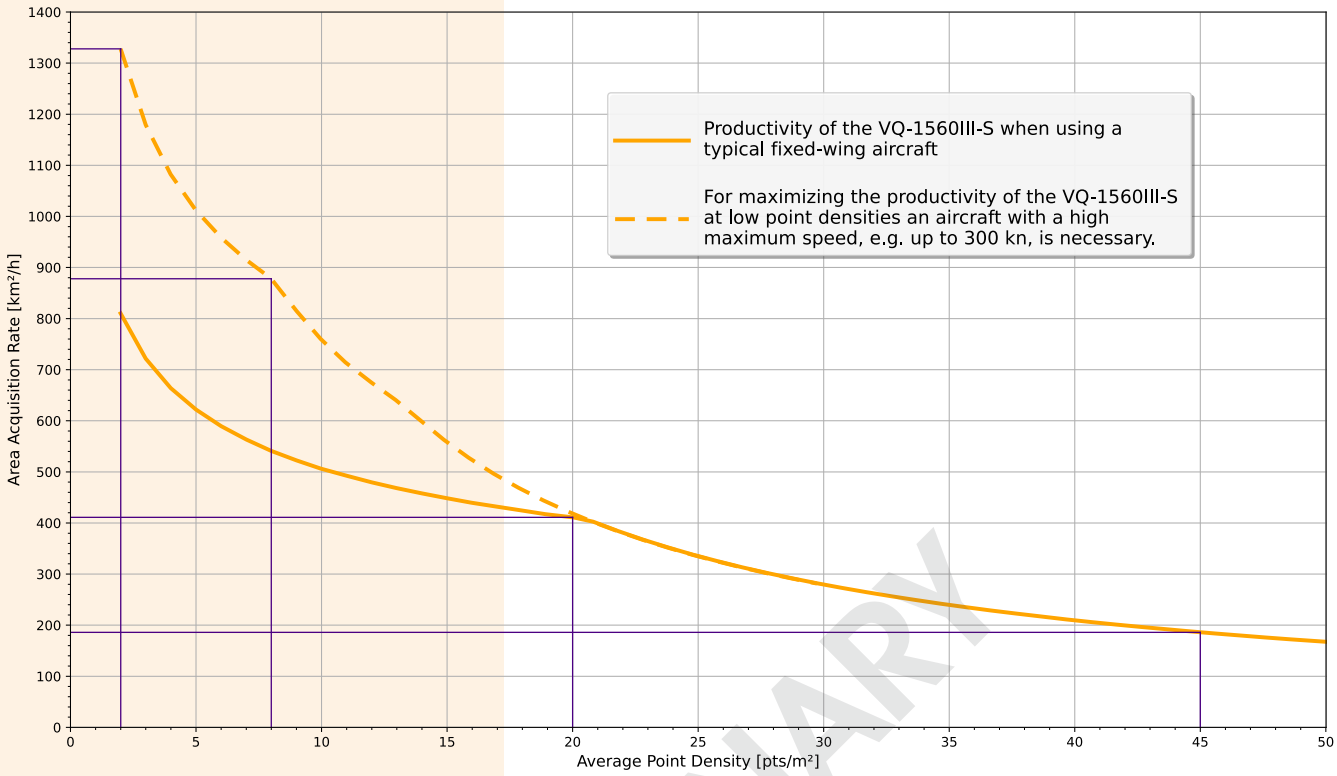
Assumptions for calculation of the Area Acquisition Rate

- 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 III-S Waveform Processing Airborne LiDAR Mapping System offers highest productivity.



Examples [1]

Average Point Density	2 pts/m²	8 pts/m²	20 pts/m²	45 pts/m²
Flight Altitude	8750 ft 2670 m	5790 ft 1760 m	5410 ft 1650 m	3730 ft 1140 m
Ground Speed	300 kn	300 kn	150 kn	99 kn
Swath Width	2990 m	1980 m	1850 m	1270 m
Productivity	1328 km²/h	878 km²/h	411 km²/h	186 km²/h
eff. Measurement Rate [2]	922,000 meas./sec	2,440,000 meas./sec	2,835,000 meas./sec	2,909,000 meas./sec
Camera GSD [3] [4]	200 mm	133 mm	124 mm	85 mm
Camera Trigger Intervall [4]	5.5 sec	3.7 sec	6.9 sec	7.2 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 2200 kHz
Max. Measuring Range [2] [3] [4]				
natural targets ρ ≥ 20 %	4740 m	3720 m	2800 m	1990 m
natural targets ρ ≥ 60 %	7040 m	5670 m	4370 m	3180 m
Max. Operating Flight Altitude [2] [5] (AGL) [6]				
natural targets ρ ≥ 20 %	3880 m 12750 ft	3050 m 10000 ft	2290 m 7500 ft	1630 m 5350 ft
natural targets ρ ≥ 60 %	5770 m 18900 ft	4640 m 15250 ft	3580 m 11750 ft	2610 m 8550 ft
NOHD [7] [9]	421 m (414 m [10])	309 m (305 m [10])	217 m (215 m [10])	143 m (142 m [10])
ENOHD [8] [9]	3012 m (2702 m [10])	2209 m (2035 m [10])	1554 m (1464 m [10])	1035 m (993 m [10])
Number of Targets per Laser Pulse up to [11]	31	31	15	7
Sample block length up to [12]	244 m	132 m	66 m	30 m

Laser Power Level	50%	25%	12%	6%
Laser Pulse Repetition Rate (PRR) [1]	2 x 2200 kHz	2 x 2200 kHz	2 x 2200 kHz	2 x 2200 kHz
Max. Measuring Range [2] [3] [4]				
natural targets ρ ≥ 20 %	1460 m	1060 m	750 m	540 m
natural targets ρ ≥ 60 %	2380 m	1750 m	1250 m	910 m
Max. Operating Flight Altitude [2] [5] (AGL) [6]				
natural targets ρ ≥ 20 %	1190 m 3900 ft	870 m 2850 ft	610 m 2000 ft	440 m 1450 ft
natural targets ρ ≥ 60 %	1950 m 6400 ft	1430 m 4700 ft	1030 m 3350 ft	740 m 2450 ft
NOHD [7] [9]	97 m (97 m [10])	63 m (63 m [10])	34 m (34 m [10])	19 m (19 m [10])
ENOHD [8] [9]	716 m (694 m [10])	480 m (469 m [10])	283 m (277 m [10])	134 m (132 m [10])
Number of Targets per Laser Pulse up to [11]	7	7	7	7
Sample block length up to [12]	30 m	30 m	30 m	30 m

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 60°, additional roll angle up to ± 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 0.013° (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) The atmospheric attenuation of the laser beam is taken into account assuming standard clear conditions with a visibility of 23.5 km. Absorption by water vapor and carbon dioxide is neglected.
11) when using online waveform processing
12) when using full waveform recording

Minimum Range [13]	100 m
Accuracy [14] [15] / Precision [15] [16]	20 mm / 20 mm
Laser Pulse Repetition Rate	2 x 270 kHz up to 2 x 2200 kHz, selectable in steps of less than 1%
Effective Measurement Rate	up to 2 x 1.47 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 [17], typ. 0.23 mrad @ 1/e² [18]

13) Limitation for range measurement capability, does not consider laser safety issues! The minimum range for valid reflectivity values is 250 m.
14) Accuracy is the degree of conformity of a measured quantity to its actual (true) value.
15) Standard deviation one sigma @ 250 m range under *RIEGL* test conditions.
16) Precision, also called reproducibility or repeatability, is the degree to which further measurements show the same result.
17) Measured at the 1/e points. 0.18 mrad correspond to an increase of 18 cm of beam diameter per 1000 m distance.
18) Measured at the 1/e² points. 0.25 mrad correspond to an increase of 25 cm of beam diameter per 1000 m distance.

Technical Data to be continued at page 10

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 [1] - 600 lines/sec
Angular Step Width $\Delta\vartheta$	$0.006° \leq \Delta\vartheta \leq 0.100°$ [2] [3]
Angle Measurement Resolution	0.001°

1) The minimum scan rate depends on the selected laser PRR.
2) The minimum 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 10/100/1000/2500/5000/10000 MBit/s)
Scan Data Output	LAN 10/100/1000/2500/5000/10000 MBit/s)
Synchronization	Serial RS-232 interface, TTL input for 1 pps synchronization pulse, accepts different data formats for GNSS-time information
Camera Interface	2 connectors with power, RS-232, pps, trigger, exposure
Removable Storage Device	2x U.2 SSD, up to 15.36 TByte each

General Technical Data

Power Supply / Power Consumption	20 - 32 V DC / typ. 500 W max. 750 W, depending on integrated optional components
Main Dimensions (flange diameter x height)	Ø 524 mm x 726 mm (without flange mounted carrying handles)
Weight	approx. 65 kg without any camera but including a typical IMU/GNSS unit approx. 70 kg with optional components
Protection Class	IP54
Max. Flight Altitude operating / not operating	18500 ft (5600 m) above MSL[4] / 18500 ft (5600 m) above MSL
Temperature Range operation / storage	-5°C up to +35°C / -10°C up to +50°C

4) Mean Sea Level

Recommended IMU/GNSS System [5] [6]

IMU Accuracy [7]	
Roll, Pitch	0.0025°
Heading	0.005°
IMU Sampling Rate	200 Hz
Position Accuracy (typ.)	0.05 m - 0.1 m

5) The recommended IMU is listed neither in the European Export Control List (i.e. Annex 1 of Regulation (EU) No. 2021/821 nor in the Canadian Export Control List. Detailed information on certain cases will be provided on request.
6) The *RIEGL* VQ-1560 III-S Laser Scanning system supports different IMU/GNSS Systems, details on request.
7) one sigma values, no GNSS outages, post-processed with base station data

Optional Components VQ-1560 III-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°
Data Storage	1x U.2 SSD, up to 15.36 TByte each
Secondary Camera	Different camera types including thermal or NIR cameras can be integrated, details on request.

RIEGL® LASER MEASUREMENT SYSTEMS

RIEGL Laser Measurement Systems GmbH, *Headquarters*
RIEGL USA Inc., *Headquarters North America*

RIEGL Japan Ltd.
RIEGL China Ltd.
RIEGL Australia Pty Ltd.
RIEGL Canada Inc.
RIEGL UK Ltd.
RIEGL Asia Pacific Ltd.
RIEGL South America SpA
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