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

RIEGL VQ-1560i

- *high laser pulse repetition rate: up to 2 MHz*
- *up to 1.33 million measurements per second on the ground*
- *offers 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 20 pulses simultaneously in the air*
- *offers 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*
- *mounting flange for interfacing with typical hatches and stabilized platforms*
- *detachable handgrips for facilitated handling*

The new ultra high performance, fully integrated and calibrated Dual Channel Airborne Mapping System *RIEGL* VQ-1560i makes use of *RIEGL*'s sophisticated waveform processing LiDAR technology enabling an excellent multiple-target detection capability and Multiple-Time-Around (MTA) processing. The system is capable of online waveform processing as well as full or smart waveform recording, resulting in unsurpassed information content on each single target.

The new VQ-1560i provides a laser pulse repetition rate of up to 2 MHz resulting in more than 1.3 million measurements per second on the ground and operates at an altitude of up to 15,500 ft. That allows operation at varying flight altitudes resulting in a wide range of point densities. Thus, the system is ideally suited for aerial survey of ultra wide areas as well as of complex urban environments. By the way, faster and more efficient flight planning and safer flights are enabled.

The *RIEGL* VQ-1560i comes with a unique and innovative forward/backward looking capability. This enables capturing data from multiple angles more effectively and more accurately at high point density. With its large field of view of 58 degrees and its widely variable scan parameters the system enables highly efficient scan data acquisition.

The system is equipped with a seamlessly integrated high performance IMU/GNSS system. An 100 megapixel RBG camera and the capability to integrate a secondary IR camera complete the system. All individual components are integrated into a compact design and equipped with a mounting flange for simple interfacing with typical hatches or gyro-stabilized leveling mounts.

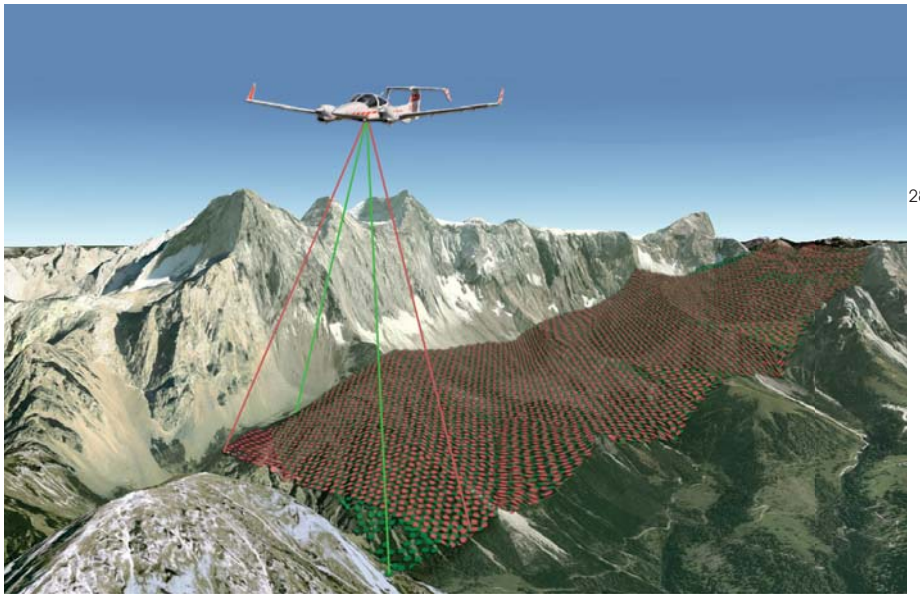
Applications:

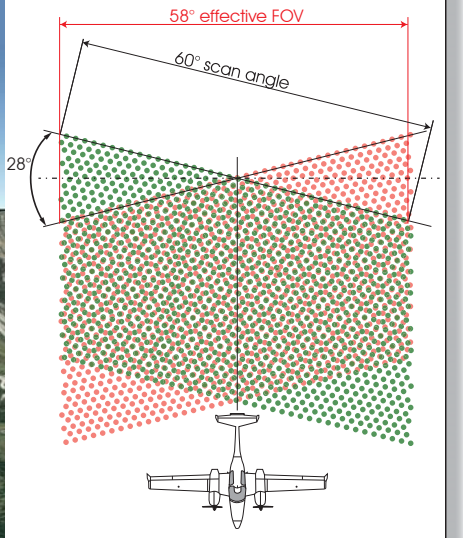
- *Ultra Wide Area / High Altitude Mapping*
- *High Point Density Mapping*
- *Mapping of Complex Urban Environments*
- *Glacier & Snowfield Mapping*
- *City Modeling*
- *Mapping of Lakesides & River Banks*
- *Agriculture & Forestry*
- *Corridor Mapping*

visit our website
www.riegl.com

RIEGL®
LASER MEASUREMENT SYSTEMS

RIEGL VQ-1560i Scan Pattern

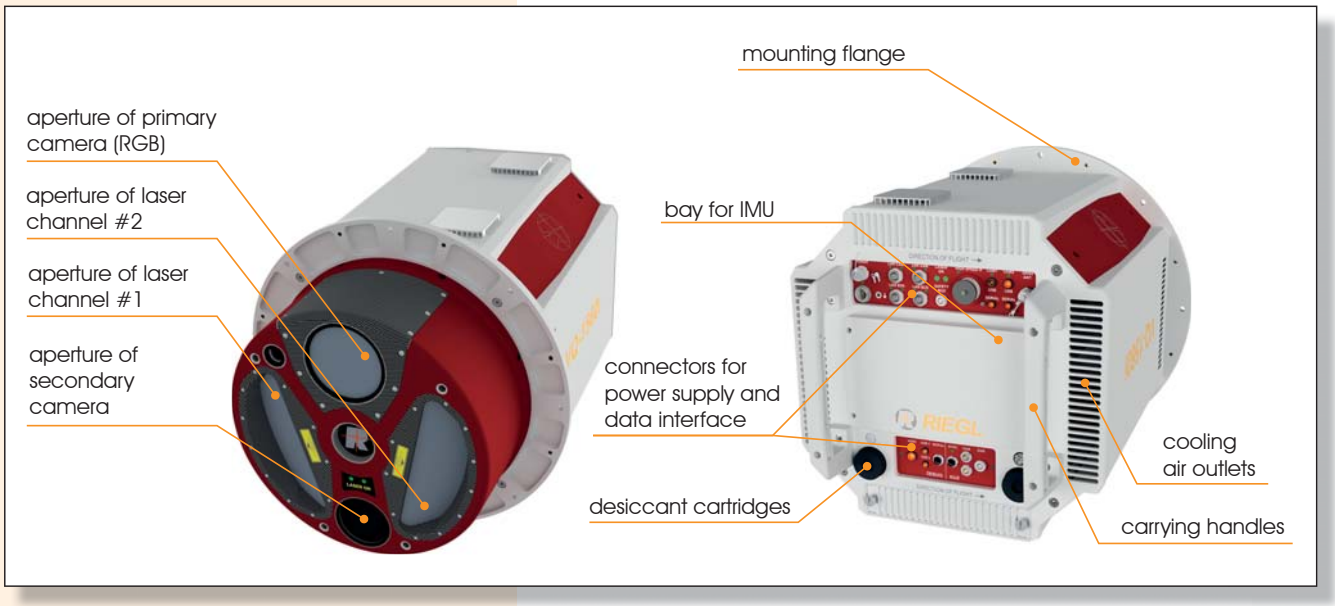




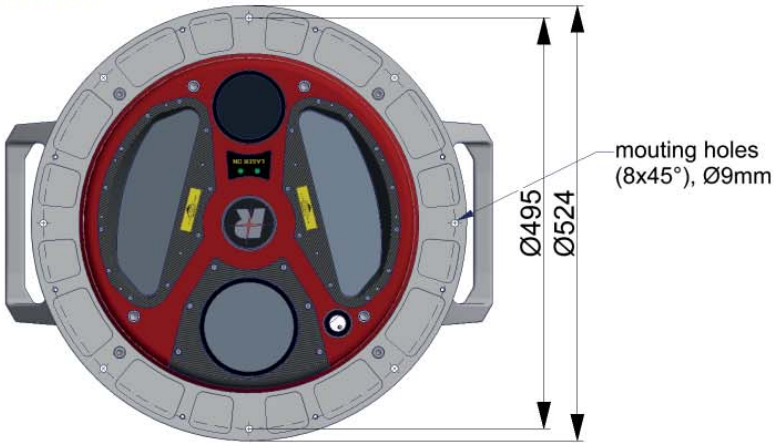
Each channel delivers straight parallel scan lines. The scan lines of the two channels are tilted against each other by 28 degrees providing an optimum distribution of the measurements on the ground invariant to changes in terrain height.

Tilt Angle of Scan Lines	**+/- 14°**
Forward/Backward Look in Non-Nadir Direction	**+/-8° at the edges**

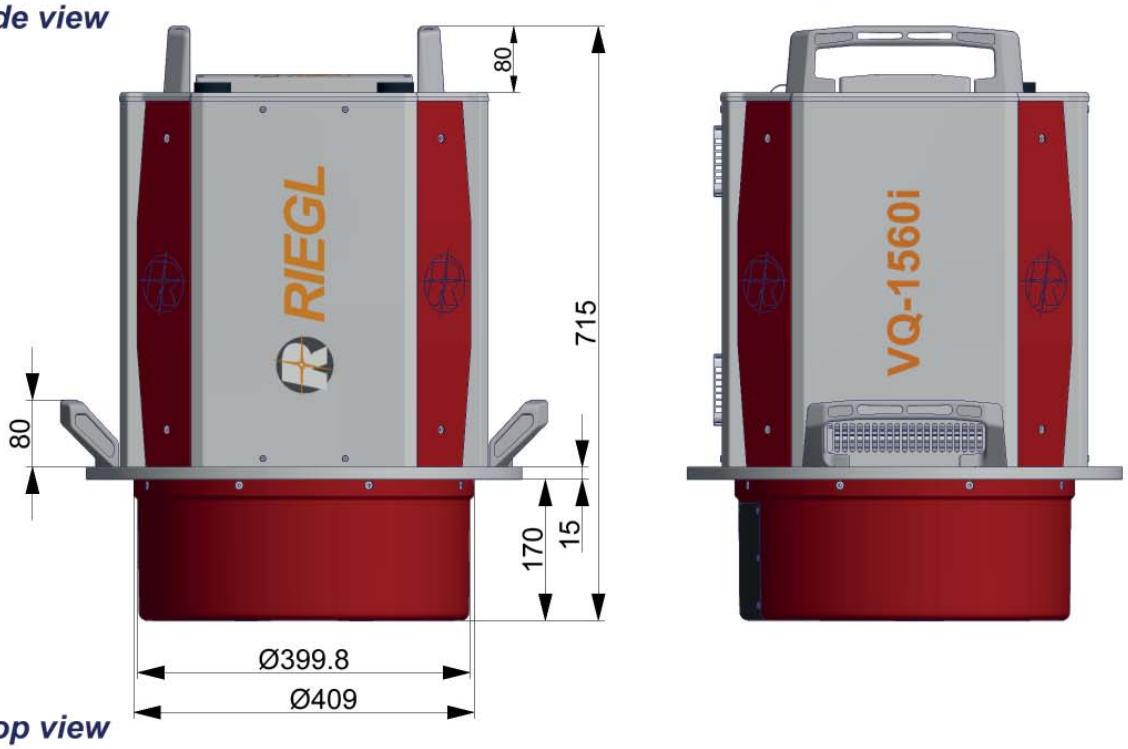
RIEGL VQ-1560i Elements of Function and Operation



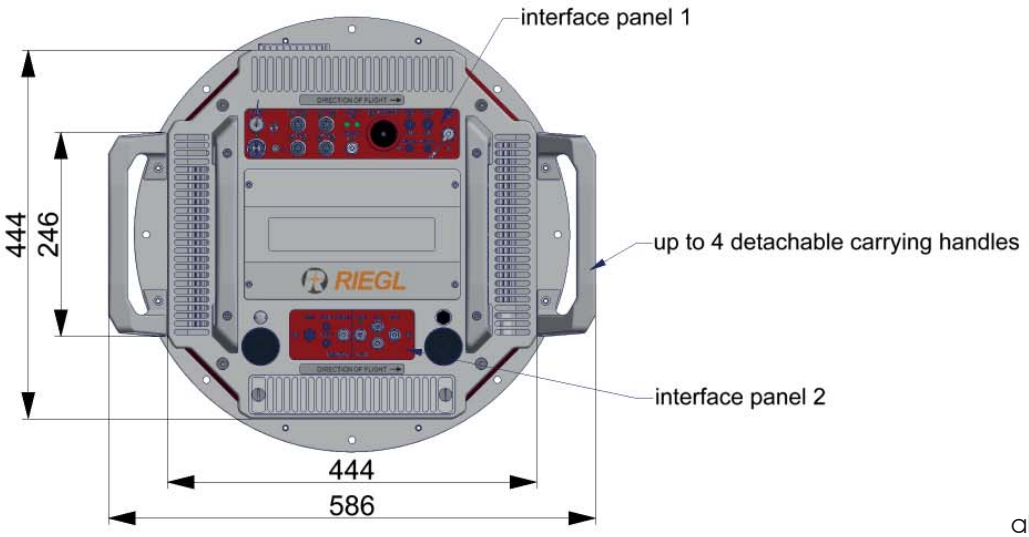
bottom view



side view

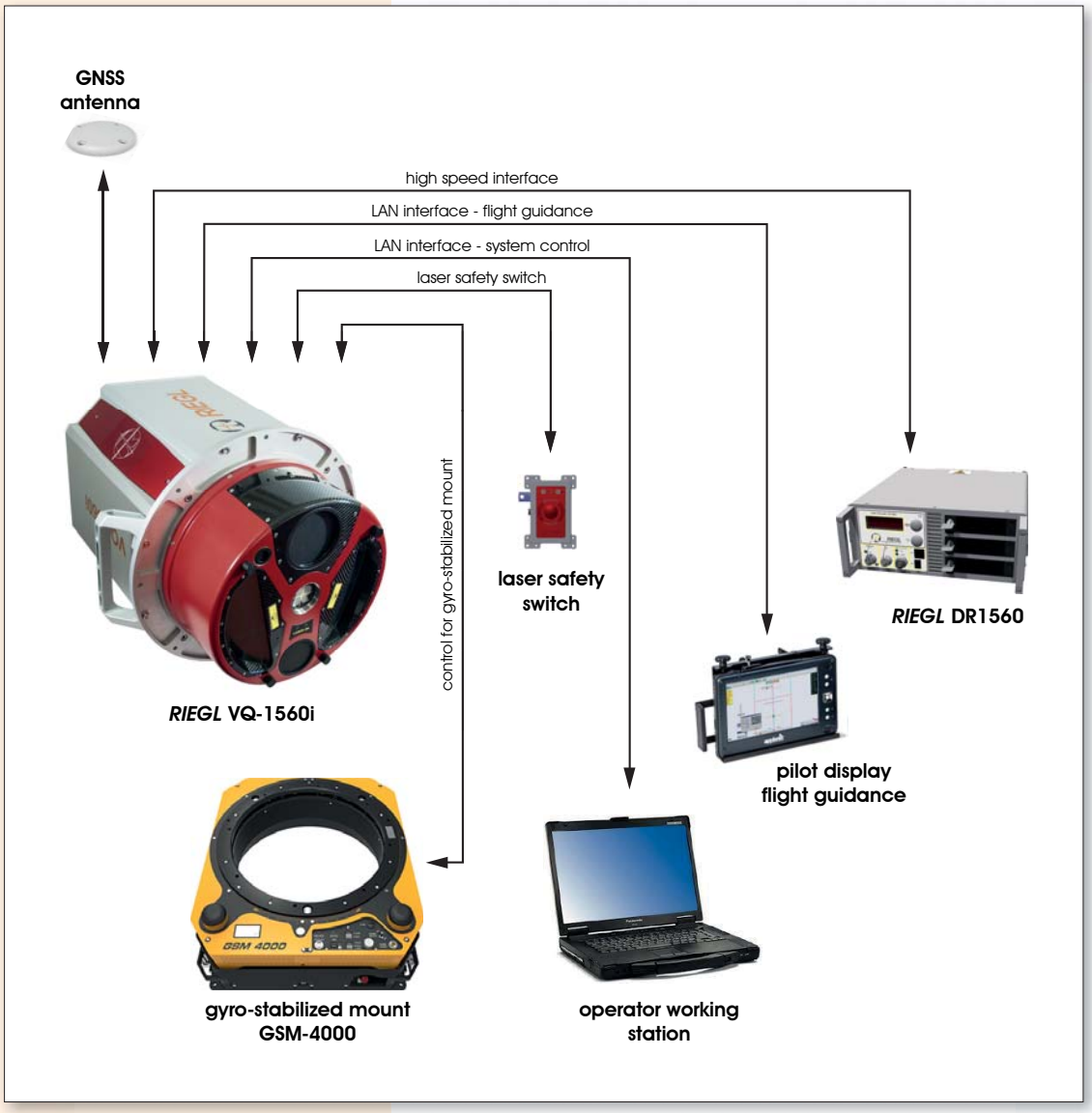


top view



all dimensions in mm

RIEGL VQ-1560i System



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

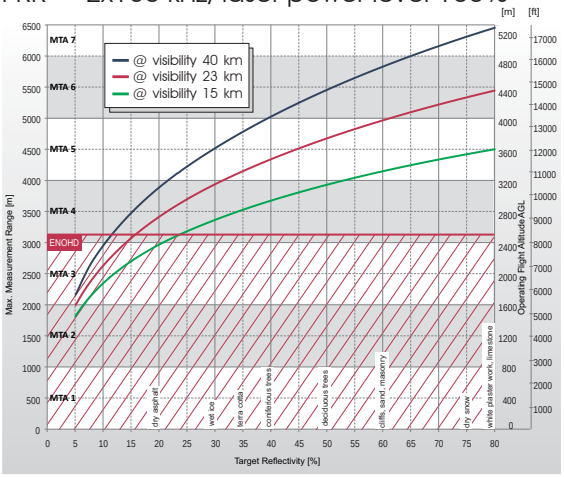
RIEGL VQ-1560i Installation Examples

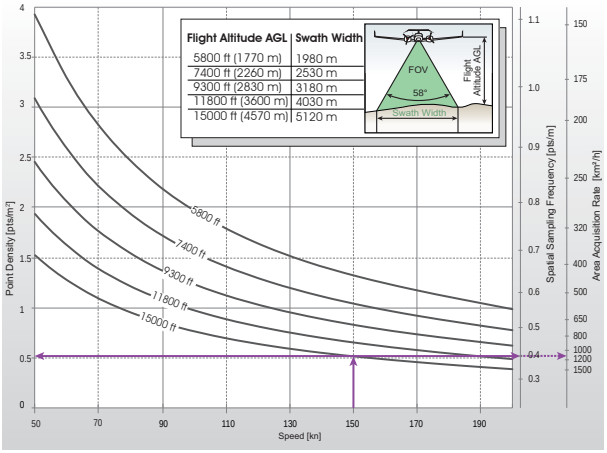
RIEGL VQ-1560i installed in the nose pod of fixed-wing aircraft **DA42 MPP**

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

Measurement Range & Point Density *RIEGL* VQ-1560i

PRR = 2x150 kHz, laser power level 100%

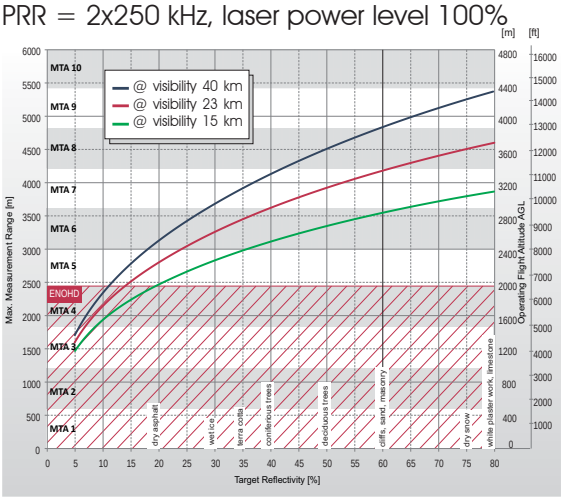


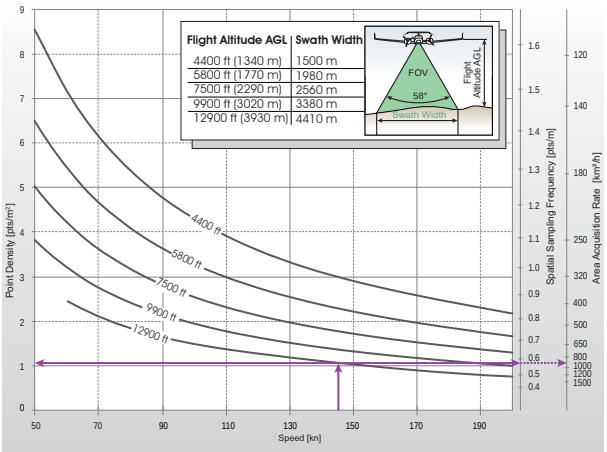


Example: VQ-1560i at 2 x 150,000 pulses/sec, laser power level 100%
Altitude = 15,000 ft AGL, Speed = 150 kn

Results: Point Density ~ 0.51 pts/m²
Spatial Sampling Frequency ~ 0.40 pts/m
Area Acquisition Rate ~ 1130 km²/h

PRR = 2x250 kHz, laser power level 100%

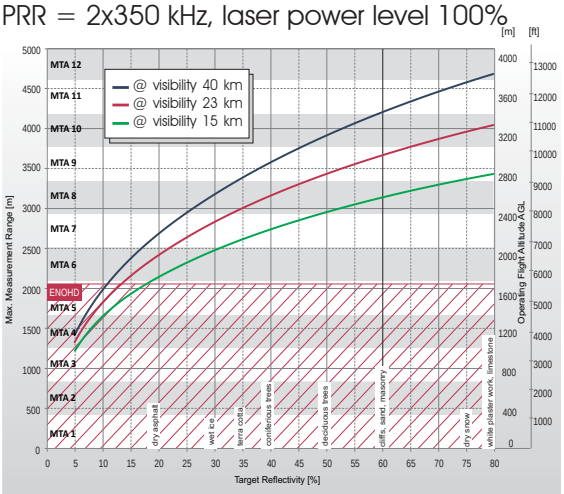


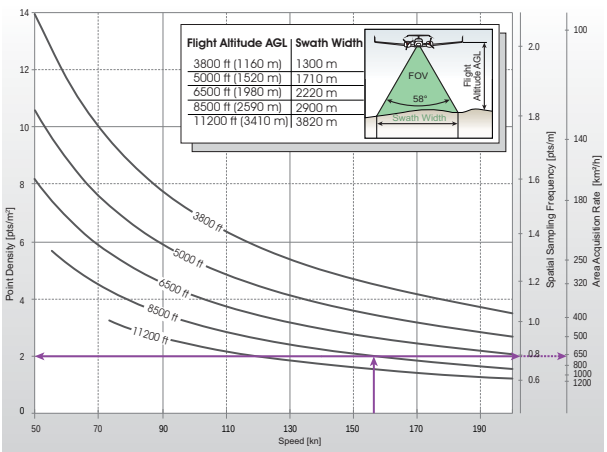


Example: VQ-1560i at 2 x 250,000 pulses/sec, laser power level 100%
Altitude = 12,900 ft AGL, Speed = 145 kn

Results: Point Density ~ 1.01 pts/m²
Spatial Sampling Frequency ~ 0.56 pts/m
Area Acquisition Rate ~ 950 km²/h

PRR = 2x350 kHz, laser power level 100%





Example: VQ-1560i at 2 x 350,000 pulses/sec, laser power level 100%
Altitude = 8,500 ft AGL, Speed = 155 kn

Results: Point Density ~ 2 pts/m²
Spatial Sampling Frequency ~ 0.79 pts/m
Area Acquisition Rate ~ 670 km²/h

The following conditions are assumed for the Operating Flight Altitude AGL

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

Assumptions for calculation of the Area Acquisition Rate

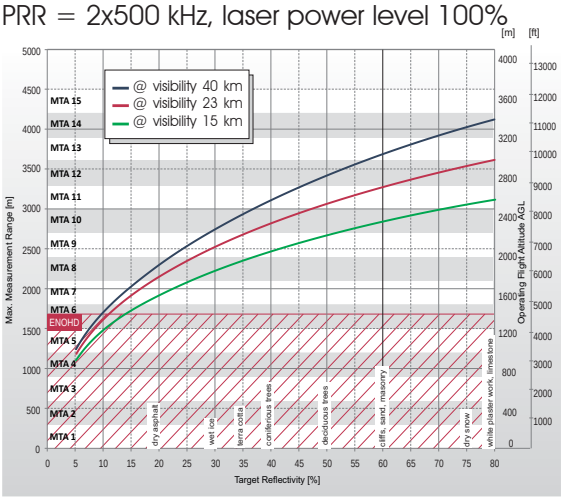
- 20% overlap of neighboring flight strips. This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

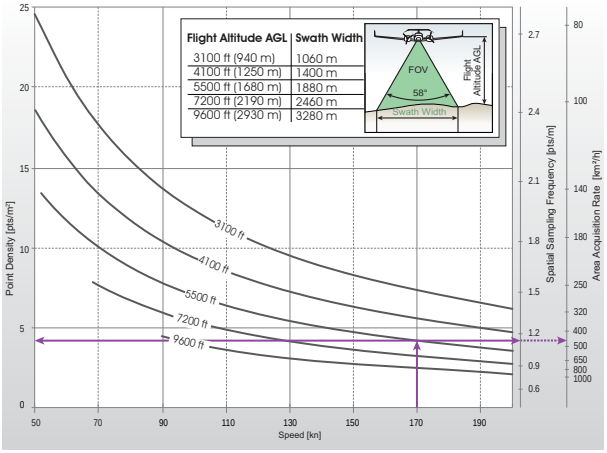
Definition of the Spatial Sampling Frequency

- The Spatial Sampling Frequency is the reciprocal of the 95th percentile of the distribution function of the maximum distances between neighboring scan points. When considering any individual scan point, the probability to find its most distant neighbor within the reciprocal of the Spatial Sampling Frequency is 95%.

Measurement Range & Point Density *RIEGL* VQ-1560i

PRR = 2x500 kHz, laser power level 100%

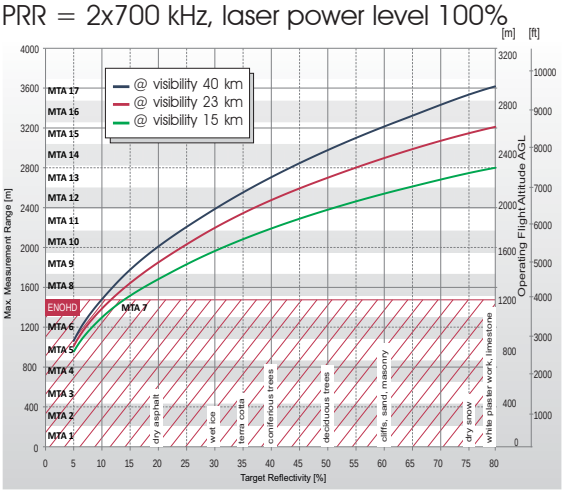


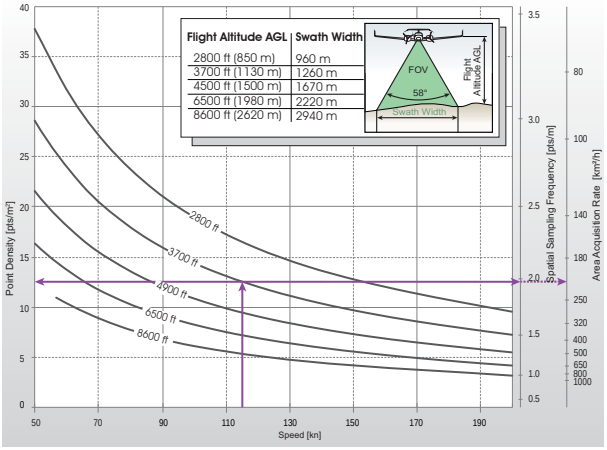


Example: VQ-1560i at 2 x 500,000 pulses/sec, laser power level 100%
Altitude = 5,500 ft AGL, Speed = 170 kn

Results: Point Density ~ 4 pts/m²
Spatial Sampling Frequency ~ 1.1 pts/m
Area Acquisition Rate ~ 470 km²/h

PRR = 2x700 kHz, laser power level 100%

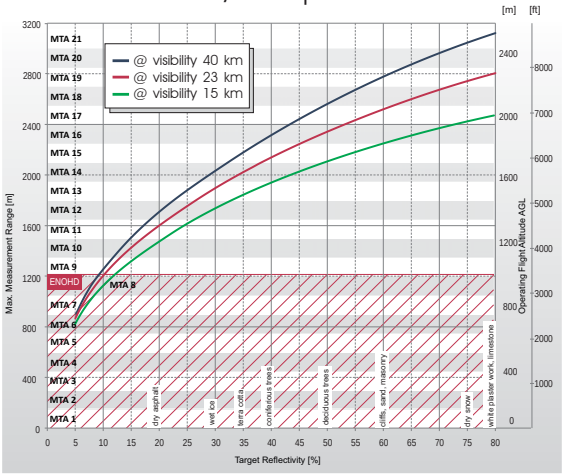


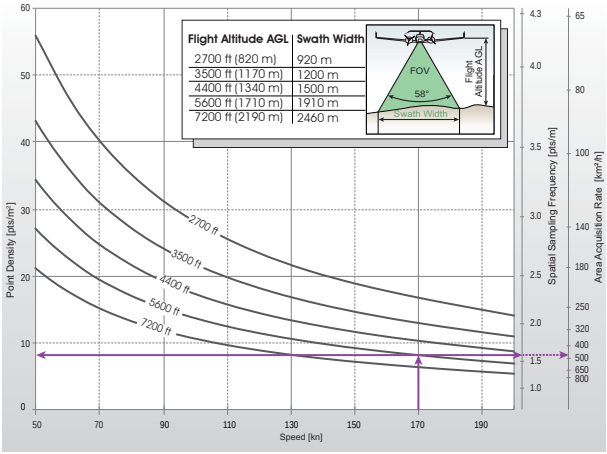


Example: VQ-1560i at 2 x 700,000 pulses/sec, laser power level 100%
Altitude = 3,700 ft AGL, Speed = 115 kn

Results: Point Density ~ 12.5 pts/m²
Spatial Sampling Frequency ~ 2 pts/m
Area Acquisition Rate ~ 215 km²/h

PRR = 2x1000 kHz, laser power level 100%





Example: VQ-1560i at 2 x 1,000,000 pulses/sec, laser power level 100%
Altitude = 5,600 ft AGL, Speed = 170 kn

Results: Point Density ~ 8 pts/m²
Spatial Sampling Frequency ~ 1.6 pts/m
Area Acquisition Rate ~ 480 km²/h

The following conditions are assumed for the Operating Flight Altitude AGL

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

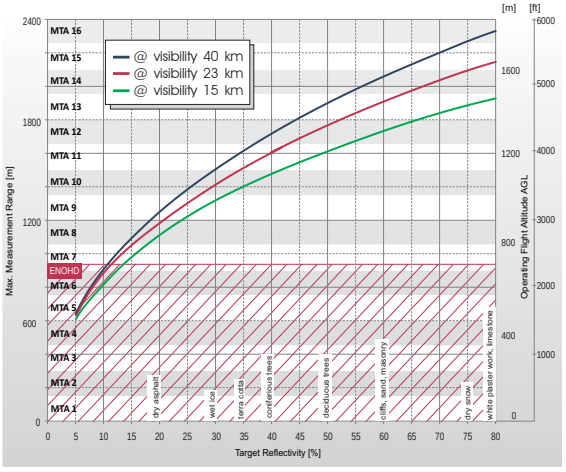
Assumptions for calculation of the Area Acquisition Rate

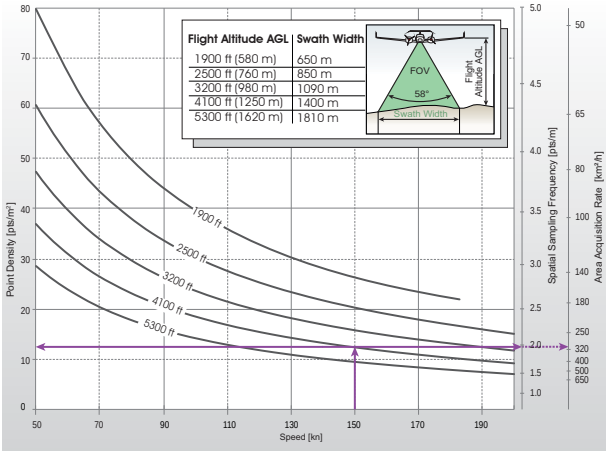
- 20% overlap of neighboring flight strips. This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

Definition of the Spatial Sampling Frequency

- The Spatial Sampling Frequency is the reciprocal of the 95th percentile of the distribution function of the maximum distances between neighboring scan points. When considering any individual scan point, the probability to find its most distant neighbor within the reciprocal of the Spatial Sampling Frequency is 95%.

PRR = 2x1000 kHz, laser power level 50%

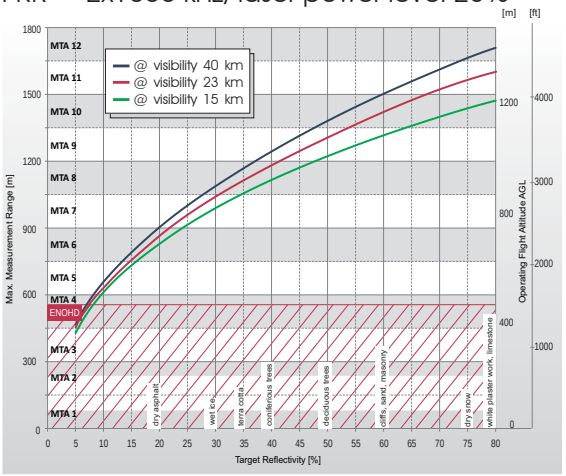


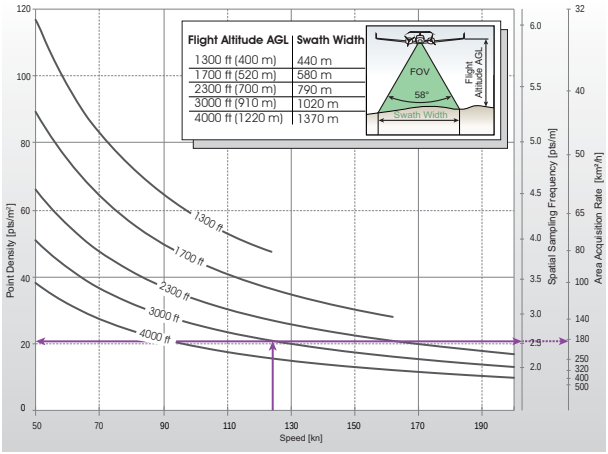


Example: VQ-1560i at 2 x 1,000,000 pulses/sec, laser power level 50%
Altitude = 4,100 ft AGL, Speed = 150 kn

Results: Point Density ~ 12.3 pts/m²
Spatial Sampling Frequency ~ 2 pts/m
Area Acquisition Rate ~ 310 km²/h

PRR = 2x1000 kHz, laser power level 25%

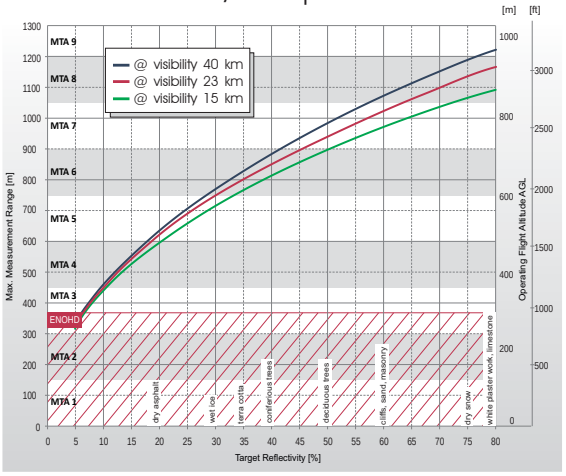


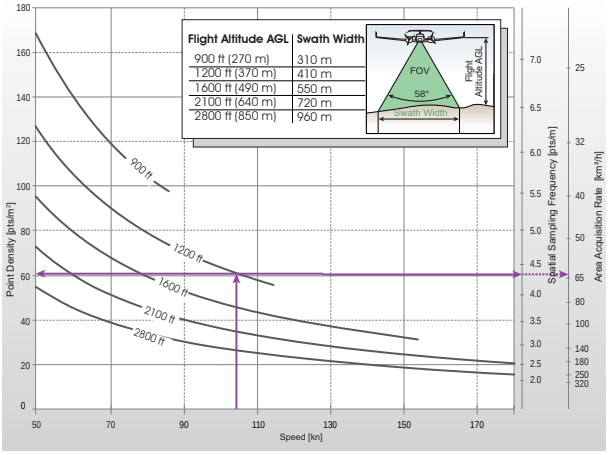


Example: VQ-1560i at 2 x 1,000,000 pulses/sec, laser power level 25%
Altitude = 3,000 ft AGL, Speed = 125 kn

Results: Point Density ~ 20.2 pts/m²
Spatial Sampling Frequency ~ 2.5 pts/m
Area Acquisition Rate ~ 190 km²/h

PRR = 2x1000 kHz, laser power level 12%





Example: VQ-1560i at 2 x 1,000,000 pulses/sec, laser power level 12%
Altitude = 1,200 ft AGL, Speed = 105 kn

Results: Point Density ~ 60.2 pts/m²
Spatial Sampling Frequency ~ 4.3 pts/m
Area Acquisition Rate ~ 64 km²/h

The following conditions are assumed for the Operating Flight Altitude AGL

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

Assumptions for calculation of the Area Acquisition Rate

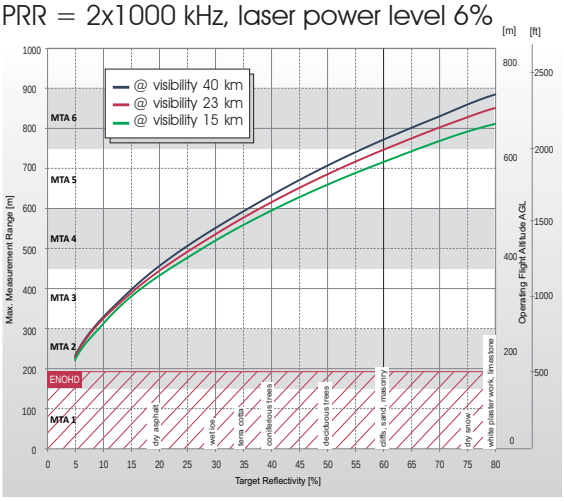
- 20% overlap of neighboring flight strips. This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

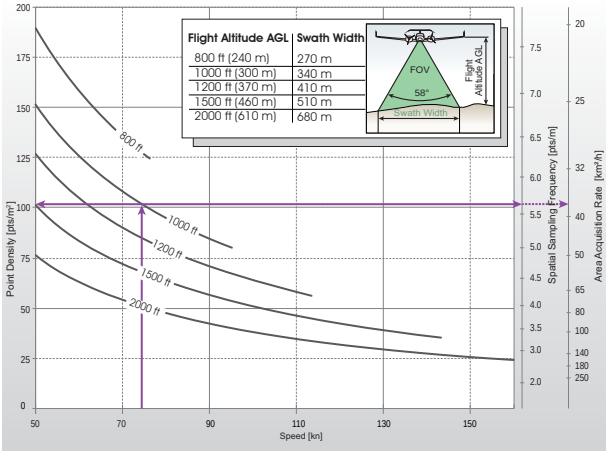
Definition of the Spatial Sampling Frequency

- The Spatial Sampling Frequency is the reciprocal of the 95th percentile of the distribution function of the maximum distances between neighboring scan points. When considering any individual scan point, the probability to find its most distant neighbor within the reciprocal of the Spatial Sampling Frequency is 95%.

Measurement Range & Point Density *RIEGL* VQ-1560i

PRR = 2x1000 kHz, laser power level 6%





Example: VQ-1560i at 2 x 1,000,000 pulses/sec, laser power level 6%
Altitude = 1,000 ft AGL, Speed = 75 kn

Results: Point Density ~ 101 pts/m²
Spatial Sampling Frequency ~ 5.6 pts/m
Area Acquisition Rate ~ 38 km²/h

The following conditions are assumed for the Operating Flight Altitude AGL

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

Assumptions for calculation of the Area Acquisition Rate

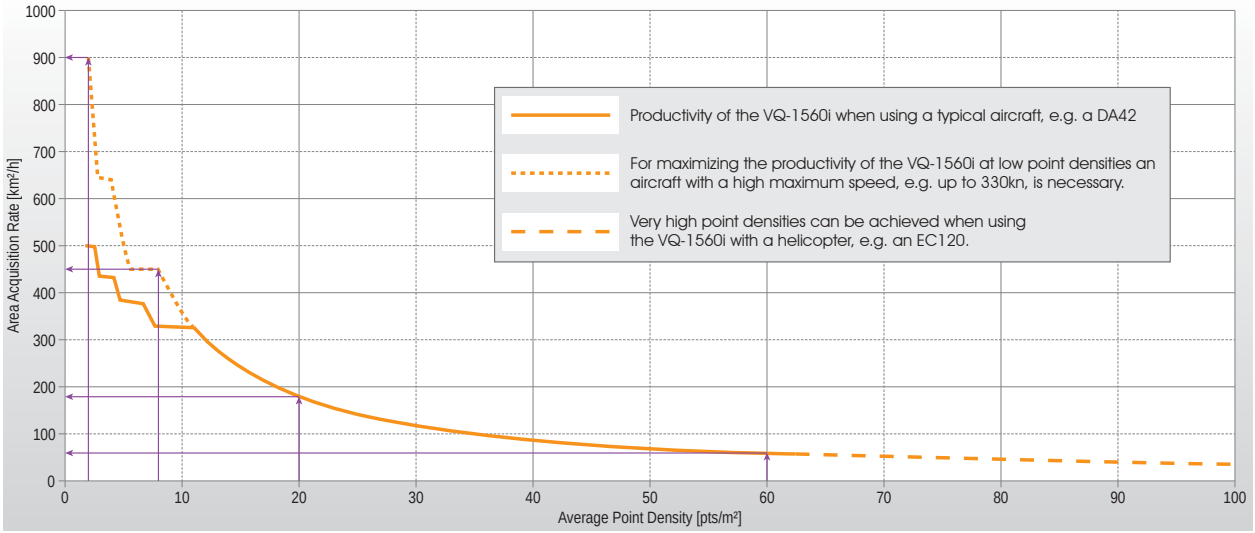
- 20% overlap of neighboring flight strips. This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

Definition of the Spatial Sampling Frequency

- The Spatial Sampling Frequency is the reciprocal of the 95th percentile of the distribution function of the maximum distances between neighboring scan points. When considering any individual scan point, the probability to find its most distant neighbor within the reciprocal of the Spatial Sampling Frequency is 95%.

RIEGL VQ-1560i Productivity

The *RIEGL* VQ-1560i 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	6000 ft 1830 m	4500 ft 1370 m	3300 ft 1000 m	1150 ft 351 m
Ground Speed	315 kn	210 kn	115 kn	110 kn
Swath Width	2040 m	1540 m	1130 m	400 m
Productivity	900 km²/h	450 km²/h	180 km²/h	60 km²/h
Measurement Rate [2]	660 000 meas./sec	1.33 mill meas./sec	1.33 mill meas./sec	1.33 mill meas./sec

1) calculated for 20% target reflectance and 25% 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.

Technical Data *RIEGL* VQ-1560i

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 deviations pursuant to Laser Notice No. 50, dated June 24, 2007.

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

Range Measurement Performance [1]

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

Laser Power Level	100%				
Laser Pulse Repetition Rate (PRR) [2]	2 x 150 kHz	2 x 250 kHz	2 x 350 kHz	2 x 500 kHz	2 x 700 kHz
Max. Measuring Range [3] [4]					
natural targets ρ ≥ 20 %	3800 m	3100 m	2700 m	2300 m	2000 m
natural targets ρ ≥ 60 %	5800 m	4800 m	4200 m	3600 m	3200 m
Max. Operating Flight Altitude Above Ground Level (AGL) [3] [5]	4700 m 15500 ft	3900 m 12900 ft	3400 m 11200 ft	2900 m 9600 ft	2600 m 8600 ft
NOHD [6] [7]	370 m	290 m	240 m	200 m	170 m
ENOHD [7] [8]	2650 m	2050 m	1730 m	1440 m	1220 m

Laser Power Level	100%	50%	25%	12%	6%
Laser Pulse Repetition Rate (PRR) [2]	2 x 1000 kHz	2 x 1000 kHz	2 x 1000 kHz	2 x 1000 kHz	2 x 1000 kHz
Max. Measuring Range [3] [4]					
natural targets ρ ≥ 20 %	1700 m	1200 m	900 m	630 m	450 m
natural targets ρ ≥ 60 %	2700 m	2000 m	1500 m	1050 m	770 m
Max. Operating Flight Altitude Above Ground Level (AGL) [3] [5]	2200 m 7200 ft	1600 m 5300 ft	1200 m 4000 ft	860 m 2800 ft	630 m 2000 ft
NOHD [6] [7]	140 m	95 m	61 m	36 m	21 m
ENOHD [7] [8]	1010 m	700 m	480 m	300 m	160 m

1) with online waveform processing
2) rounded average PRR
3) 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.
4) 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 amiguities have to be resolved by multiple-time-around processing.
5) Typical values for reflectivity ρ ≥ 60 %, max. effective FOV 58°, additional roll angle ± 5°
6) Nominal Ocular Hazard Distance, based upon MPE according to IEC60825-1:2007, for single pulse condition
7) NOHD and ENOHD have been calculated for a typical angular step width of 0.012° which means non-overlapping laser footprints. NOHD and ENOHD increase when using overlapping laser footprints which may be intended e.g. for power line mapping.
8) Extended Nominal Ocular Hazard Distance, based upon MPE according to IEC60825-1:2007, for single pulse condition

Minimum Range [9]	50 m
Accuracy [10] [11]	20 mm
Precision [11] [12]	20 mm
Laser Pulse Repetition Rate	up to 2 MHz
Effective Measurement Rate	up to 1.33 MHz @ 60° scan angle
Echo Signal Intensity	provided for each echo signal
Laser Wavelength	near infrared
Laser Beam Divergence [13]	≤ 0.25 mrad
Number of Targets per Pulse	with online waveform processing: unlimited [14]
	monitoring data output: first pulse

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 Look 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 [15]	40 - 600 lines/sec
Angular Step Width Δϑ [16] [17]	Δϑ ≥ 0.006°
Angle Measurement Resolution	0.001°

9) Limitation for range measurement capability, does not consider laser safety issues!
10) Accuracy is the degree of conformity of a measured quantity to its actual (true) value.
11) Standard deviation one sigma @ 250 m range under *RIEGL* test conditions.
12) Precision, also called reproducibility or repeatability, is the degree to which further measurements show the same result.
13) Measured at the $1/e^2$ points. 0.25 mrad correspond to an increase of 25 cm of beam diameter per 1000 m distance.
14) Practically limited only by the maximum data rate allowed for the *RIEGL* Data Recorder.
15) The minimum scan rate depends on the selected laser PRR and laser power level.
16) The minimum angular step width depends on the selected laser PRR and laser power level.
17) The maximum angular step width is mainly limited by the maximum scan rate.

Technical Data to be continued at page 10

Technical Data *RIEGL* VQ-1560i *(continued)*

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 DR1560
Synchronization	Serial RS232 interface, TTL input for 1 pps synchronization pulse, accepts different data formats for GNSS-time information

General Technical Data

Power Supply / Current Consumption	20 - 32 V DC / typ. 250 W, max. 550 W, depending on integrated optional components
Main Dimensions (L x W x H)	444 x 586 x 715 mm, mounting flange diameter 524 mm
Weight	approx. 57 kg without any camera but including a typical IMU/GNSS approx. 65 kg with optional components
Protection Class	IP54
Max. Flight Altitude operating / not operating	18500 ft (5600 m) above Mean Sea Level MSL / 18500 ft (5600 m) above MSL
Temperature Range	0°C up to +40°C (operation) / -10°C up to +50°C (storage)

Optional Components VQ-1560i

Please note: The INS and the camera configuration of the *RIEGL* VQ-1560i Laser Scanning System can be customized.

RGB Camera

Sensor Resolution	up to 100 MPixel CMOS without FMC or up to 80 MPixel CCD with FMC
Sensor Dimensions (diagonal)	67.2 mm (medium format)
Focal Length of Camera Lens	50 mm
Field of View (FOV)	approx. 56.2° x 43.7°
Interface	USB 3.0
Data Storage	via GigE to *RIEGL* Data Recorder DR1560

Thermal Camera

Spectral Range	7.5 - 14 μm
Sensor Resolution	1024 x 768 Pixel
Temperature Measuring Range	-40°C up to +1200°C
Focal Length of Camera Lens	15 mm
Field of View (FOV)	approx. 60° x 47°
Interface	GigE
Data Storage	via GigE to *RIEGL* Data Recorder DR1560

Recommended IMU/GNSS System [1]

IMU Accuracy [2]	
Roll, Pitch	0.005°
Heading	0.008°
IMU Sampling Rate	200 Hz
Position Accuracy (typ.)	0.05 m - 0.3 m

1) 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.
2) One sigma values, no GNSS outages, post-processed with base station data

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