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LIDAR

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SCALABILITY
Points clouds and terrain models support rail project

EXPRESSION
Structured light scanning for human head modeling

FLUCTUATION
Scanning moving objects using motion correction

INNOVATION IN 3D

INNOVATION

RIEGL LASER MEASUREMENT SYSTEMS

> "Be silent, if you choose; but when it is necessary, speak—and speak in such a way that people will remember it."
>
> —Wolfgang Amadeus Mozart

Riegl's newest product, the LMS-Q1560 airborne mapping system.

BY MARC CHEVES, PS

With great anticipation we attended the 2013 Riegl User Conference held in June in the beautiful city of Vienna, Austria. In grand Viennese tradition, 265 attendees from more than 40 countries were treated to quality at every level, from the opening keynotes to an airport visit where several Riegl partners are located. And as we learned throughout the conference and a visit to the company's headquarters in Horn afterward, details are the core of this company.

The History

From 1964 to 1969, Dr. Johannes Riegl studied radar and communications engineering at the prestigious Vienna University of Technology. There he pioneered development of the essential circuitry—in principle, unchanged to this day—for driving a semiconductor laser transmitter. He also began gathering the first of many national and internationals patents based on his research. From 1970 to 1972 he developed the first miniaturized laser

IN 3D

Diamond Airborne Sensing's GeoSTAR utilizes a Riegl instrument for Airborne LIDAR (belly) and a Vexcel camera (nose). Ideal missions include infrastructure planning, vegetation analysis and a variety of mapping functions.

A plane like a Swiss Army Knife: Diamond's *Guardian* is a flexible, multi-functional sensor carrier and an innovative composite, twin-engine aircraft all in one.

distance meters, and in 1975 developed and designed a rangefinder for use in hydrographic surveying. (At that time, GPS was not yet available!)

In 1978, after being encouraged by university colleagues to start his own company, with a handful of students he left to start Riegl Laser Measurement Systems (LMS). They began developing industrial and the first surveying applications. At one point while making a sales presentation, a manager of one of Riegl's main competitors today asked, "Why do we need to know Dr. Riegl?" This simple question became a driving force in his life.

In 1979 Riegl began experimenting with digital signal processing. In time Riegl technology was broadly adopted for such uses as tunnel profiling, rifle scopes, cargo cranes and cargo ship docking, and an application for determining the distance to the ground for a commercial airliner on a landing approach. Handheld "binoculars" came in 1982. Applications capable of withstanding high heat, such as needed in the steel industry, were also developed. 1991 brought the Lasertape, the world's first pocket-size binoculars for non-professional use, as well as a laser speed gun for law enforcement.

Between 1996 and 2008, several variations of airborne, terrestrial and industrial instruments were introduced, including the world's first digitizing and full waveform airborne unit, the LMS-Q560. In 1996 the LMS-Q140 for airborne corridor mapping was introduced. They have maintained a close relationship with the European Space Agency, developing such things as short range lasers for spacecraft docking. In 1998 they introduced the LMS-Z210 3D scanner, followed by the LMS-Z420i long-range instrument in 2003, and the LMS-Z620 very long-range instrument in 2008. 2008 also marked

Dr. Martin Pfennigbauer, Director of Research and Intellectual Property,

Dr. Johannes Riegl, CEO and founder of Riegl LMS.

Dr. Andreas Ullrich, Chief Technology Officer.

the introduction of a new terrestrial product family: the VZ-400 was the world's first online waveform processing 3D laser scanner. Today, the VZ family consist of the VZ-400 and its sister types VZ-1000, VZ-4000 and VZ-6000, the last providing up to 6 kilometer range, and are applicable for a broad variety of applications, from architecture and crime scene investigation, to mining and long range monitoring applications. In 2009, they entered the mobile scanning arena, and debuted the VMX-250 to the world at Intergeo in Karlsruhe.

The Management Team in Horn

Dr. Andreas Ullrich joined the company in 1991. He studied communications and radio frequency and obtained a PhD in in electrical engineering with a thesis on "high resolution optical Doppler radar" from the Vienna University of Technology. He is currently the CTO and has played an integral part in the LMS success during his 23-year tenure.

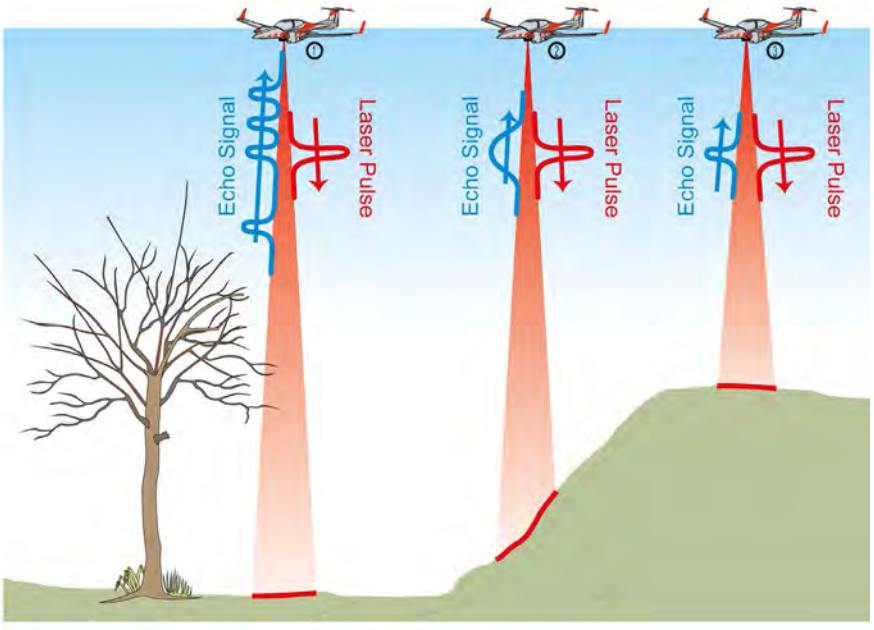
Dr. Martin Pfennigbauer, another graduate of the Vienna University of Technology, with studies in communications engineering and a PhD in electrical engineering, joined the company in 2005 and is currently director of research and intellectual property. Pfennigbauer's work at the university—used by ESA—included satellite-to-satellite and satellite-to-ground communications. Because signals from space are weak, his research on sensitive detectors fits well with laser return signals.

Rounding out the management team is Johannes Riegl Jr. He holds a masters degree in Business Management from the University of Applied Sciences in Vienna. As the Chief Marketing Officer for Riegl, Johannes is responsible for the highly successful Riegl conferences, and also manages advertising, PR, business development, and related commercial initiatives.

The Vienna University of Technology is obviously fertile ground for the recruitment of bright young engineers and scientists, and Ullrich still teaches there. The senior members of the company—particularly Ullrich and Pfennigbauer—have written dozens of technical papers, and the company has received numerous awards for its achievements. Today the office in Horn has 155 employees.

Riegl USA in Orlando

Since 1992, the American face of Riegl LMS has been Riegl USA. Opened by Theodore "Ted" Knaak in Orlando, it is the North American center of sales, training, service and support. In 2009, Knaak left and started Certainty3D, a company specializing in the application



This illustration shows the types of returns and resulting waveforms from flat ground, sloping ground, and multiple returns.

of 3D technology. Upon Knaak's departure, James van Rens, holding a combination BA/BS from Marquette University, and having served as vice president since 1997, became Riegl USA's president. With his total experience of more than 18 years in LiDAR, van Rens has been key to the seamless leadership transition and the huge growth in Riegl USA over the past five years. Today, Riegl USA has nearly 20 employees in Orlando.

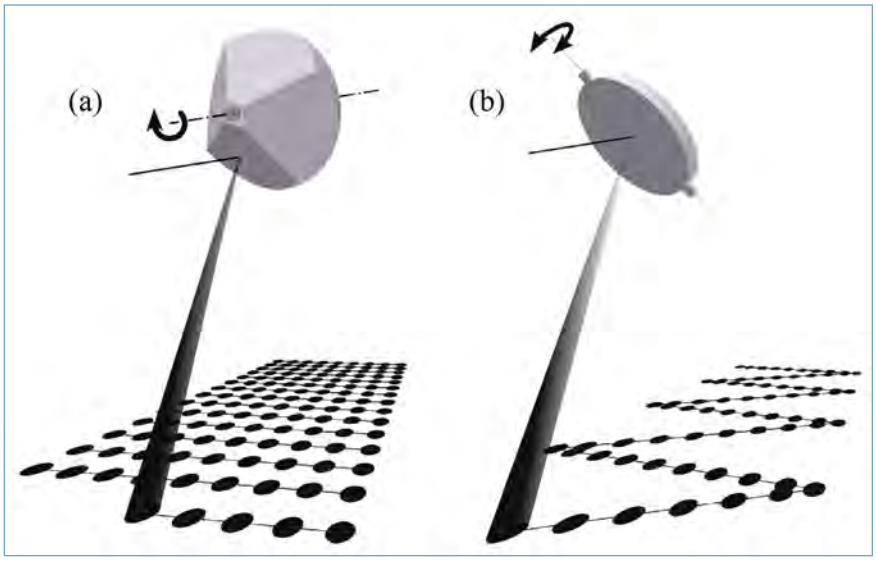
The Technology

Because of infrared-based EDMs, most surveyors can relate to the concept of timing one pulse out and back, divided by two, equaling the distance to the target. Unlike the pulsed time-of-flight lasers used by Riegl, phase-based lasers operate on the principle of the phase shift of the pulse. But what to do when there are multiple targets reflecting portions of the beam?

The size of the target spot for the laser beam grows larger the farther it is from the emitter, therefore the chances of reflection from multiple targets is even greater for an airborne laser. All airborne lasers, through various techniques, can generally distinguish between the top of a forest canopy and bare earth below the canopy, but what about the returns in between?

Likewise, terrestrial lasers confront the same problem, such as in a plant with pipes near the instrument and other features farther away. Difficulties can arise when the objects providing the returns are closer together than the length of the pulses.

Analog laser devices simply send out a pulse and wait for an echo, which, if the amplitude of the echo is above a certain threshold, is sent along the circuitry to be processed. These return signals contain information that can be used to determine the range to the target as well as the reflectance of the target. Reflectance is derived from the strength of the return



Riegl's unique faceted spinning mirror (left) and an oscillating mirror, showing the shot pattern on the ground.

Alastair Jenkins, President & CEO, GeoDigital (left) and James van Rens, President, Riegl USA with various Diamond Aircraft aerial platforms.

signal. It is influenced by what the target is composed of, for example, a rough or smooth surface. It is important to note that, with phase shift instruments, nothing more than range and reflectance can be gleaned from the return signal.

Riegl's lasers feature echo digitization, which uses an analog-to-digital converter to sample the analog echo, thereby making it digital. More important, the digitized echo signal allows the software to do a much better job at dealing with "pulse shape deviation." This is what is used to handle situations where the pulse hits several targets that are very close together. Also from this, the target type can be determined. The result for the user is a point cloud that contains much more information and much less noise, or unusable information.

In 2004, with the introduction of its LMS-Q560, Riegl was the first manufacturer to rely solely on digitized echo signals. This enabled "full waveform analysis," which is performed offline on stored data. It allows the user to perfectly reconstruct and effectively analyze the return signals. In 2008, Riegl introduced its V-Line instruments, which are capable of online waveform analysis within the instrument. van Rens told about a discussion he was having with Dr. Riegl regarding the use of the term real-time to describe the online analysis: Dr. Riegl refuses to allow this because there's a one one hundredth of a second delay! Another detail: meticulous about truth in advertising.

Unlike most other manufacturers that use an oscillating mirror, Riegl uses a rotating polygon mirror with three or four facets to "aim" the pulses. Oscillating mirrors, because they have to stop and reverse direction, can introduce errors. Because of this, Riegl can use almost all of the data thru the entire 60° swath, while competitors have to discard up to 5° of data on each side of the swath. Additionally, the rotating mirror creates straight, parallel scan lines on the ground, as opposed to the z-pattern made by oscillating mirrors.

The effective measurement rate—up to 266,000 per second with the LMS-Q780 at a flight height of 11,000 feet—makes it possible for up to ten pulses to be in the air at the same time. Known as multiple time around (MTA), this distinguishes the pulses for processing by use of the time tag associated with each

Colored Point Cloud, Ötscher, Austria, acquired in 2012 by an LMS-Q780. 57 km^2 scan area; 716 million points; 13 points/m^2 average point density; 27 minute scan time.

With great fanfare, the worldwide debut of the LMS-Q1560 occurred at the user conference. Left to right: Dr. Andreas Ullrich, James van Rens, Johannes Riegl, Jr., and Dr. Johannes Riegl.

pulse, in addition to other proprietary techniques. The benefits of MTA for the user are higher flight altitude, denser point spacing on the ground, and a higher pulse repetition rate.

One problem revealed by traditional aerial LiDAR is that the instrument only points straight down with respect to the flight line. This means, for example, that you can "see" the bottom of an alley, but not the walls on either side. Based on user feedback from some who were using two instruments and physically tilting them to provide a forward and backward looking capability, Riegl debuted its latest achievement at the 2013 user conference: the LMS-Q1560 airborne mapping system. According to the company and those we spoke to, it marks a new era in airborne laser scanning. Through clever faceting of the mirror, the LMS-Q1560 looks forward and backward by 8°. To provide better point spacing on the ground, the two channels in the instrument are tilted with respect to each other by 28 degrees. Most LiDAR RFPs call for specified point spacing, usually referred to as *x* points per square meter. Riegl's Matrix Scan Pattern provides dense spacing both across and between scan lines, delivering dozens of points per square meter.

Incorporating two laser sources—creating "crossfire" and a resulting effective measurement rate of 532,000 pulses per second—the LMS-Q1560 enables another important innovation: a level flight path. Maintaining the same height above unlevel terrain has always posed challenges, particularly with vertical features such as cliffs. With its forward/backward-looking capability, the LMS-Q1560 solves those problems. Additionally, flight times are reduced and flights are safer. The unit also incorporates an integrated medium format aerial camera, space for a second camera such as an infrared unit, an INS/GNSS, and fiber optic links for high-speed data transfer, all fully integrated and calibrated in one turnkey system.

Other Current Products

Riegl is divided into four distinct groups: aerial, terrestrial, mobile and industrial, each with its own full software suites. Each group presents its own challenges: for example, there have been reports that some mobile scanning systems have had difficulty ensuring that each subsequent point cloud can be "joined" to the previous

High-tech board manufacturing in the factory.

one on long corridor surveys. Keeping this in mind, Riegl wasn't first in the mobile arena, but the company ensured that its mobile units do not have this problem. *Note:* While this article focuses on Riegl's aerial products, a future article in *The American Surveyor* will focus more on its terrestrial products, as well as a unique American employee in Horn.

Riegl's Partners in Austria

A highlight of the user conference came on the last day when attendees got to visit a small airport southwest of Vienna where several Austrian partners are located. Each partner produces world-class aerial platforms that can utilize Riegl aerial instruments. First was Airborne Technologies, an integrator that specializes in combining various technologies to provide customized turnkey solutions and sensor integration for airborne police, military, and environmental and mapping/exploration applications. Next was Diamond Airborne Sensing, a subsidiary of Diamond Aircraft Industries, the third largest general aviation aircraft manufacturer in the world. Diamond's gorgeous multi-purpose platform aircraft includes one owned by Riegl LMS. A highlight of the day for me was a plane ride in the Riegl aircraft, piloted by Dr. Riegl himself. Last but not least was a visit to Schiebel Aircraft, maker of high-end helicopter UAVs. These multi-sensor UAVs are being used mostly by military and security forces around the world.

Visit to Riegl Headquarters in Horn, Austria

After the user conference, we traveled about an hour northwest of Vienna to Horn for a meeting with the Riegl team and a wide-ranging discussion about the company. I inquired as to why the

CUSTOMER EXPERIENCE

Two of Riegl's long-time customers, Alastair Jenkins and Bobby Tuck, were at the user conference. Jenkins even signed a purchase order for a Q1560 during the event. We asked each of them what it's like to work with Riegl:

"The reliability of the Riegl devices and the stability of their calibration is legendary. While other suppliers use flapping mirrors which are driven by a galvanometer and use some form of sensor to detect the angle of the mirror, the Riegl airborne sensors all use spinning polygons. Once calibrated, they scan consistently and reliably. This improved accuracy reduces our field calibration efforts by almost an order of magnitude versus other sensors. The radiometric calibration and intrinsic wave form analysis used by Riegl systems allows us to extract information that is simply not available with other sensors. The most recent generation of Riegl sensors incorporate true multi pulse in the air technology allowing high altitude operation without needing to reduce laser repetition rate."

— Alastair Jenkins, President & CEO, GeoDigital International Inc.

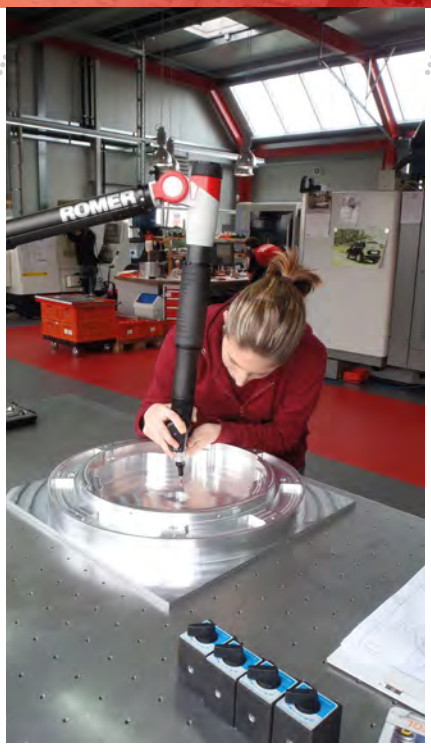
Dr. Riegl discussing the various aerial instruments during the factory tour after the user conference.

company hasn't been acquired, and Dr. Riegl explained that an acquisition would have hampered innovation: "It's not about growth, it's about making things work better." Indeed, Riegl has grown significantly over the past few years while much of the geo-industry has languished. "That is because the LiDAR industry is anti-cyclic," says Dr. Riegl. Growth has come from diversifying and enhancing with different applications and niches. He believes the industry doesn't need to grow to prosper and that 3D data collection and measurement has a great future.

Keys to the company's success are clear: offer a full package, and pre- and post-sales support; stay hungry and driven; design for human beings; and offer ultimate reliability and availability all over the world. As an example of this last, Dr. Riegl proudly told of a unit that performed well for 15 years before needing service. The equipment is intricately machined from aluminum, which acts as a heat sink, rather than plastic which does not, even though plastic is easier to work with.

Looking to the future, the company will pursue higher flight altitudes, higher density of points on the ground, and a higher pulse repetition rate. They will also investigate sensors with different wavelengths, and refined interpretation of the data. Capitalizing on the trajectory capability of the RiProcess software, they will investigate indoor uses of their equipment.

> "I've been a Riegl user for more than 13 years, and I've found that the products are built to withstand the environment. In all this time, I've only had one problem, and that was with a computer virus that got into the data recorder. When I've visited the factory, I've marveled at the fact that the houses in Austria are built to last 300 years. Likewise, Riegl's equipment is built with one thing in mind: permanence. Over the years I've developed a personal relationship with Dr. Riegl and his staff. They listen to users and design products to meet the needs of the industry, not products that play catch-up with the competition. The Q1560 leapfrogs the industry with its capability."
>
> —Bobby Tuck, Owner of Tuck Mapping



6-axis measuring tool being used to check the machining of a base plate for an LMS-Q1560.

An intensely private man, whose hobbies that include flying and water skiing may reveal an intrepid streak, is circumspect when it comes to giving advice. His success speaks quietly for itself. Dr. Riegl's $50 million company has more than succeeded in what he set out to do in 1978. Integrating technologies and data that has been gathered, processed and presented in a cost-efficient and timely manner is an equation that works. In true Viennese style, Riegl LMS continues to define the state of the art.

Marc Cheves is the editor of *The American Surveyor.*