According to Riegl, data acquisition from the air, especially in flat areas, provides LiDAR data of the highest quality

Looking at it another way

How are changing geophysics technologies helping to create successful, efficient exploration projects for new and growing mines? Donna Schmidt checks in with a few experts

Every mine's life cycle begins with exploration; it is the definitive way to determine if a mining operator's money will be well invested into its future. It is also crucial to a company's growth later as it determines if, where and how to expand its footprint.

Luckily, while many of the old standby methods of exploration form the basis of today's practices, geophysics technologies for mineral exploration look much different to how the industry could have envisioned even a few decades ago. Operators and consultants alike look to drones, aerial mapping, laser scanning, software visualisation and 3-D imaging and more to give them the most accurate picture of what can be seen, as well as what is hidden beneath the surface.

MM recently spoke to several global companies about these evolving technologies, the elements of a successful mineral exploration programme and what is driving the details of tomorrow's projects.

RIEGL ZEROES IN

Riegl, producer of terrestrial and unmanned laser scanners, points out that drill optimisation technology is crucial due to its cost-intensive process. Thomas Gaisecker, who serves as manager of the company's mining business division, says that one great way to optimise is by pairing a highly accurate, detailed digital terrain model of an outcrop and the surrounding areas with further geophysics technology that provides underground information.

Riegl's sensors use light detection and ranging (LiDAR) to gather data under harsh conditions and, because of full waveform processing technology, can also penetrate dense vegetation down to the ground. It is advancements like the company's unmanned laser scanning (ULS), which acquires its survey data with unmanned aerial vehicles (UAVs), that are at the forefront of how the industry is, and will continue, to get its comprehensive views.

"Data acquisition from the air, especially in flat areas, provides LiDAR data of the highest quality," according to Gaisecker. "However, classical airborne or helicopter flights are associated with high costs. UAVs present themselves as a perfect alternative for exploration projects in areas for which classical ALS (airborne laser scanning) is too expensive."

In the mining sector, this is also the case, he notes, because of the distance between airfields and open-cast mining sites, and in some cases the size of the project can be relatively small. Adding complexity to that situation is the need for data acquisition at regular and often relatively short intervals.

Using remotely controlled surveying platforms, though, allows those required targets to be more efficiently achieved. "ULS allows the efficient use of classic ALS with all its advantages for smaller projects," he explains.

Riegl's line of LiDAR sensors and laser scanning systems are able to be integrated with common UAVs and the company's own RiCopter ready-to-fly, remotely-piloted ►

"Geophysics technologies for mineral exploration look different to how the industry could have envisioned a few decades ago"

airborne laser scanning system. Its terrestrial laser canning (TLS) models include the RIEGL VZ-400i, VZ-2000i, VZ-4000, and VZ-6000; its ULS models include the VUX-1UAV, miniVUX-1UAV and the new RIEGL VUX-240.

GOING AERIAL WITH AIROBOTICS

Airobotics' marketing vice president Kathy Kim, says the company, which utilises drone automation technology to collect aerial data and provide insight, has a mission to enable a 'new dimension' of data and immediate insight to the industries in which it works, mining included.

"Automated drones have come to represent an essential role in mining"

As the company has grown, its most beneficial applications for mining have been digital terrain modelling, evaluating stockpile information, monitoring, drilling and blasting analysis, hauling optimisation, tailings dam inspection and general project oversight. In the coming years, that will expand to include more environmental monitoring and even using UAVs for incident response.

It is clear, then, the essential role that automated drones have come to represent in mining – not only for their perspective, but as Kim says, they very effectively bridge the gap between decisionmakers and the critical data on which they rely.

"Airobotics…is the only solution that automates the entire operation," she says. She adds that the automation element comprises preflight checks all the way through to automatic data download and transmission.

"Additionally, by taking the drone pilot out of the equation, we removed the most expensive and hard-to-find element of industrial drone operations."

Among the features of Airobotics' drone system is its capability to swap batteries and payloads via a robotic mechanism. This allows for the unit to keep its mission types and payloads diverse.

Because of its fully automated platform, the system can self-launch as well as land accurately with no need for an operator or drone pilot. The airbase, the exterior of which is constructed of industrial-grade materials, is entirely sealed, keeping it weather and corrosion resistant.

Putting it all together provides exploration projects with a streamlined experience, boosting efficiency of the work being performed and offering easy and immediate access to the data compiled.

"[This is] all without loading and transporting the drone, having to wait for the survey, or being dependent on a service provider replacing manual inspections in the most hazardous areas and collecting critical information, while drastically reducing the time and manpower required," Kim adds.

As for where the future lies for geophysics technology in mining exploration, Airobotics believes it is all about locating economically viable deposits in the shortest possible amount of time, and at the lowest possible cost.

"The greatest challenge today is the depletion of most resources at the surface, or near subsurfaces, resulting in the ever-increasing difficulty in locating valuable ore. The imperative for innovation and technologies to provide exploration companies with a competitive advantage has never been more crucial," says Kim.

Other developments feeding the industry's innovation appetite, according to the company, are satellite and airborne sensors to assist with geological, geophysical and geochemical data collection, along with 3-D modelling systems to aid operators in managing data for better visualisation, analyses and interpretation.

"From Airobotics' perspective, leveraging an automated drone system will be a natural extension to how exploration companies currently

Riegl's ULS line includes the miniVUX-1UAV

manage their data collection and analytics," Kim says. She notes that the automation it provides will be able to deliver extended ground coverage – an element of planning more frequently desired by exploration companies.

She calls it a 'future state' for mining; however, for now the technology is limited by battery technology, which currently comprises lithium cells.

Another element is the readiness of industry-standard sensors and payloads that can be fitted to the Airobotics drone.

"Commonly used imaging methods in exploration include hyperspectral and electromagnetic means. These payloads on average weigh more than 10kg, rendering them close to impossible for a drone to carry," Kim explains. "A substantial payload would require heavier battery capacity as well."

That said, Airobotics believes the demand is significant enough for lithium cell capacity to exponentially grow. At the same time, the demand from exploration will also lead to the further development of smaller, lighter payloads with ground-penetrating abilities to give operators further precision and the ability to identify feasible orebodies.

Airobotics says it has a mission to enable a 'new dimension' of data and immediate insight via automated UAVs

In December 2018, Airobotics announced it had received a certificate of waiver (CoW) from the US Federal Aviation Administration (FAA) for flying beyond visual line of sight (BVLOS) in the US, Australia and Israel. It is the first company in the US to receive this certificate.

THE HARD LINE ON SOFTWARE

Hexagon product manager Seth Gering and support specialist Jennifer Hare say software can come to the aid of operations, from exploration to management, and even final closure and remediation. The most successful technologies the company has seen for mining have been those that both streamline and optimise workflows with its platform offering visualisation and analysis.

"Drones and low-cost sensors are another set of technologies changing the industry"

"Miners are under tremendous pressure to meet deadlines and make informed decisions quickly [and] the best tools help miners to do their jobs by providing information to optimise and understand processes quickly instead of spending time compiling this information manually," the pair says.

"The solutions we see that are the most successful are those that eliminate process[es] of compiling information manually, provide 3-D visualisation that can be easily shared with all stakeholders across the organisation, provide the data quickly to the user so that they can make informed decisions [and] the use of optimisation algorithms provides solutions that show the economic cost and benefits analysis of making those decisions."

Hexagon believes the industry's future direction is multi-faceted, with more integrated and automated systems that bring together information from various areas such as geology, slopes, drill/blast, engineering, hydrology and geophysics to give a complete picture of what lies beneath the surface. Drones and low-cost sensors are another set of technologies changing the industry by providing data more accurately, more rapidly and less expensively than ever before.

The most successful and efficient mineral exploration projects are realised, Gering and Hare say, when there are clearly defined questions for the project, paired with communication between stakeholders. The questions can be answered using ever-expanding technologies including software platforms for modelling, visualisation and statistical analysis to manage multiple datasets.

Technology can also be used to determine other essential information, including: preliminary/historical data; pre-survey feasibility studies to choose survey methods and optimise survey design variables; assessing critical rock properties and characterising surface geotechnical properties and hydrogeologic settings; and more.

"Developing best practices for the deployment of integrated systems, as well as for generating quantitative earth models quickly and efficiently from multiple datasets will be of paramount importance for the real-world, cost-effective, field applicability of both mining exploration surveys and environmental monitoring campaigns," Gering notes.

Geophysics in the future, they add, will use current technology in innovative ways and put interoperability into focus. Drones, scanners, IoT platforms, and other advancements such as consumer electronics and wireless devices are changing the geophysical concepts that have remained relatively unchanged for many years, and are making collection faster, easier and safer.

Hare says that instrumentation measurement precision advancements have had an impact on the sector, giving mining companies an opportunity to monitor very small changes in subsurface properties over time scales that can range from days to decades. Geophysical technologies available include reflection and refraction seismic, gravity, magnetic, electrical, electromagnetic, radiometric survey methods and sensors.

"In addition to traditional instruments and sensors, MEMS (Micro Electro Mechanical Systems [miniaturised mechanical devices]), fibre-optic sensors, and laser scanners are available. When this information is combined with other data in the mine such as hydrology, geology and engineering it can provide key insights to what is below the surface or how environmental conditions are changing over time and…the effects of those changes," Hare explains. An example would be microgravity surveys involving surface and borehole for mapping local, 3-D density distribution at the resource level.

Hexagon's software platforms, such as MinePlan3D, can manage large datasets from photogrammetry, LiDAR and geophysical data from surface and borehole exploration and monitoring arrays, and can provide interpretation and visualisation of the data.

LOOKING DEEP WITHIN WITH QUANTEC

Geophysical services firm Quantec, founded in 1986, first focused on 2-D deep earth imaging and has grown over the past decade to its position in the three-dimensional geophysical imaging world. Its Titan 24 system, and later its Orion3D system, have played roles in significant deep discoveries including one for Sierra Metals' porphyry project in October 2018.

Over his career as an exploration geophysicist, Quantec marketing and sales manager Rob Gordon has observed that while drilling will continue to make discoveries, the industry needs to improve at targeting and focusing its drilling efforts.

He likens advances in the geophysical world to the evolution of medical imaging, such as the magnetic resonance imaging (MRI) technology that is now very commonly used, and vital, after decades of continued developments.

"Recently, advances in large-scale, deep multi-parameter 3-D earth imaging technologies are coming close to providing the geoscientist with the equivalent of an MRI," Gordon explains.

"As the industry evolves and takes on an approach similar to the oil industry, which is strictly imaging

Quantec's Gordon likens advances in the geophysical engineering world to the evolving of medical imaging

AI is part of the future of geophysics, according to Quantec

before drilling, it will learn more and, ultimately, success rates per drill hole will go up."

He notes that the 'brute strength' of geophysical imaging has improved, leaving the industry with a potential to tie together geophysics and geochemistry, and ultimately geology, using advanced computing and artificial intelligence (AI).

"Much has been talked about with respect to AI, but the key issue remains: when going into new areas, what information can we do AI on? The answer is simple: geophysics," he explains. He adds that more work is ahead to characterise deposits and rocks with physical rock properties.

"Geophysics provides the best-sampled canvas for AI to integrate all the other types of data together, and paint the optimal 3-D geological image on. The issue really is that the explorer has to pull it all together. Sometimes, when too far down in the weeds, individuals simply don't have the time to make the connections."

Gordon identifies the relatively recent advances in deep electrical earth imaging as having a significant impact on the industry's ability to investigate the subsurface prior to drilling.

"Deep imaging surveys have practical applications for mapping deep structure, alteration and mineralisation," he says. "In addition, the use of these surveys for near-mine exploration continues to grow [including] planning and condemnation studies, as well as pre-tailings planning."

"Deep imaging surveys have practical applications for mapping deep structure, alteration and mineralisation"

THE CONSULTANT'S VIEW

SRK Consulting geological mapping principal consultant, Bert De Waele, notes that there are technical advances being made across all of the fields in which the company works, but the main developments have been in the field of exploration due to companies' increasing need to explore under cover.

Those technologies that have seen the most success include the use of handheld and on-the-rig geochemical and spectral analytical solutions; seismics in hard-rock mineral exploration; implicit 3-D modelling tools and integrated mineral resource estimation (MRE); digital mapping; and the application of machine learning technology.

When considering the most important elements of a successful, efficient and technologically advanced mineral exploration project, one key factor is the development of appropriate exploration strategies. At the centre of that is building a good geological understanding, regionally and locally, to identify prospectivity and possible mineralisation controls.

"Good structural and geological mapping goes a long way in developing that first-hand understanding, even in poorly exposed terranes," De Waele points out. "Under cover, geophysical techniques need to be tried and tested, but these must be designed appropriately to test for the right geophysical parameters and are dependent on an understanding of mineralisation styles and geological context. Indiscriminate use of geophysics often leads to equivocal results and poor targets."

New technologies delivering rapid results and assisting in lessening unnecessary costs are handheld XRF and spectral instruments, he notes. These technologies promote 'clever use' of both geochemistry and mineralogy (e.g. rapid spectral and mineralogical analysis).

"Additionally, digital mapping can deliver tangible benefits, along with improving multispectral satellite image data," he notes.

"The use of drones is rapidly becoming a feasible way to get high-resolution data over [a] smaller area. With the increasing payloads, drones can carry optical and multispectral sensors, LiDAR and even magnetometers. Drone technology is certainly an area to keep an eye on."

Going forward, SRK believes drone-based geophysics will become more feasible, with spectrometry, magnetics, and airborne electromagnetic and gravity techniques potentially to come in this area; however, the company notes, the latter are not yet practical.

More development and improvements are also going to be seen for ground-based, hard-rock seismic, electromagnetic and induced polarisation technologies, the firm says, and for regional-scale applications, magneto-telluric methods are gaining traction.