From stockpile and open-pit bench monitoring, to blasting analysis and exploration, Dan Gleeson looks into new and innovative uses of drones in the mining sector

Blue-sky thinking

Drones or unmanned aerial vehicles (UAV) have come a long way in a very short space of time.

Starting out, primarily in mining, as expensive pilot-operated crafts that could capture photos of surface mines or check no-one was tapping a machine's diesel line at night, they have evolved into essential monitoring tools for blasting, stockpiles, tailings dams and many other critical parts of the mining process.

Every year that passes, these machines are able to fly faster, operate for longer on a single charge and carry out more tasks.

Johnny Lyons-Baral, Senior Applications Engineer at **Hexagon Mining**, which provides a complete drone engineering solution for flight planning software, flight control, UAVs with sensors and photogrammetry processing software, says developments in the drone sector – where units are increasingly able to carry more and payloads are coming down in weight – mean this trend is set to continue.

"We're seeing a two direction confluence where the capacity of drones is going to rapidly increase to allow for multiple-sensor devices that can cover a big area in a very quick mission," he told ***IM***.

ROI

While detailed photogrammetry was initially viewed as the most obvious drone use, they are now being equipped with multiple sensors for all sorts of monitoring.

Lyons-Baral said mining companies are achieving the most return on their drone investment with blasting analysis.

"The combination of precise comprehensive surveying with video and camera inspection capabilities delivers a quick return through improved blasting safety, fragmentation, and wall control," he said.

Optimising this process, any processing plant operator will tell you, can significantly improve energy consumption and recoveries when material is fed through to the plant.

Lyons-Baral sees more drone applications coming into this field, too, with "hyperspectral mineral mapping potentially complementing blasthole sampling and updating material routing polygons.

"There is huge value to be had in this application by drastically improving correct routing to mineral processing, waste or stockpiles," he said.

Blasting analysis is one of the areas **MAXAM** sees its X-Copter (a helicopter-drone with four propellers) providing benefits, complementing a range of services and solutions to improve the productivity and safety of its customers' operations.

There is more to such analysis than video playback of the event, according to MAXAM.

"Blasting involves a large amount of information to ensure optimal design of the explosive's energy distribution," the company said.

This requires a series of checks before and during the charging process, and after blasting, all of which can be carried out with drones.

Before blasting:

- **Topography and cartography** – Generate orthomosaic and digital terrain models faster than with conventional topography;
- **Bench geometry** – Obtain high-precision 3D geometric models of the blast bench. The models obtained allow geomechanical analysis of the bench compatible with RIOBLAST software;
- **Positioning blastholes** – Actual position can be determined precisely without the need for conventional topography. The information obtained by the drone is used to update the RIOBLAST model and optimise the blasting design;
- **Safety inspections** – Help reduce the time and risks of the safety zone inspections carried out before and after blasting, inspecting a larger area without the deployment of personnel.

The development of MAXAM's X-Copter allows the company to monitor the whole blasting process

During blasting:

- **High-speed photos and video** – MAXAM's drones allow for capturing high resolution images and film high-speed video from angles impossible on land, with the added bonus of having the operator located in a safe area;
- **Gas measurement** – Real-time measurement of the gases generated in the blast (CO, NO and NO_2) guarantees safety conditions in the bench and a faster return to work, without the need to send anybody to control the area beforehand.

After blasting:

- **Bench volume measurement** – Measuring bench volumes before and after blasting provides quick, direct information to effectively secure the area;
- **Blasted material pile volume measurement** – Accurate calculation of blasted material pile and ore stockpile volumes. The work can be carried out without interrupting charging process and without sending personnel to the area;
- **Fragmentation analysis** – The images obtained with drones are optimal for semi-automatic analysis of the fragmentation obtained in the different blasting areas, without the need for scale references.

South Africa-focused miner Kumba Iron Ore is weighing up the use of drones for blasting analysis in the future.

The company currently uses four UAVs to record stockpiles and waste dumps at its Sishen and Kolomela iron ore operations in the Northern Cape.

Alton Bester, Project Manager – Mining Technology at Kumba, said the company is

already seeing a significant improvement in the way it collects and processes data from such surveys.

"We're removing a person from the pit, who would either have to go and stand in the pit or on a stockpile to carry out such surveys," he told ***IM***.

This has resulted in improved efficiency – with data processed and analysed much quicker – and increased safety of Kumba's personnel, he said.

It is not just miners realising the benefits of drone solutons.

ABB and automated drone system provider **Kespry** recently teamed up to help the former's process industry customers with important production decisions.

Kespry's drone and cloud based software system is used for stockyard inventory, mine planning, reserve exploration, reserve mapping, and site surveying; enabling customers to easily capture, view, analyse and share data with the touch of a button.

Its drones facilitate sensor fusion, which combines data from different sensors to improve performance. This provides a more complete understanding of process situations through data such as ground-based telemetry, aerial thermographic and photographic input, according to ABB.

Many of the industries served by ABB will benefit from the integration of rich aerial data collected by unmanned drones, the company said.

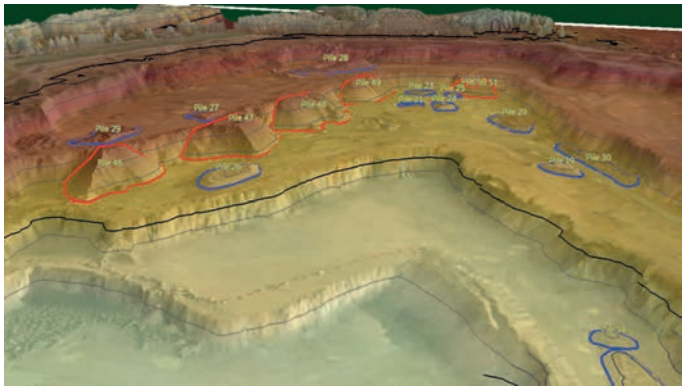
Tricky topography

Drones are not only carrying out processes quicker and safer than conventional means, they are also improving the results, according to Hexagon.

The company shared an example with ***IM*** of one such occurrence near to the Porgera Valley gold operation in Papua New Guinea, where the mine survey team had been looking for data to environmentally monitor the dump sites of a spill generated by the mine.

The team contracted Benchmark Survey & Design who, in turn, looked to Spatial Technologies of Australia for an aerial survey.

Spatial Technologies had been using Hexagon's Leica Aibot for two years to collect data in various environments, so knew the drone would be able to provide accurate results even in terrain 2,200-2,700 m above sea level.



Drones provide the ability to quantify stockpiles quickly, accurately and without exposing personnel to potential risks. Photo courtesy of Hexagon Mining

With 32 total flights of about 10 minutes each, the company collected 9,100 orthophotos at a 5 cm ground sampling distance at the two sites it was required to capture (Anjolek (380 ha) and Anawe (250 ha)).

Benchmark Survey & Design only needed sub-metre accuracy from the project, but Spatial Technologies was able to supply 10-20 cm accuracy with strategically placed controls in conjunction with the Real-Time Kinematic (RTK) capabilities of the Leica Aibot.

Combining the orthophotos from the drone with older data and point clouds of the site created by laser scanning technology allowed engineers

and environmentalists to go beyond just volume calculations, Hexagon said.

The team could see visible proof of vegetation changes and were able to conduct slope analyses.

Pinpointing new mines

There are also applications for drones within the exploration fold.

One company that has been quick on the uptake is White Gold Corp in the White Gold district of Yukon, Canada.

The company has used technical partner **Groundtruth Exploration's** Drone to Drills™ process to photograph vast areas of the district to capture outcrops and potential hand samples for geologists to follow up.

"Aerial drone surveys capture images which are combined to provide current project-scale imagery at a Ultra High Resolution and cost that was previously unobtainable resulting in an effective and efficient exploration programme," White Gold says.

These geo-referenced aerial photographs shot by drones can be followed up by a detailed geophysical survey and, if warranted, drilling as part of GroundTruth's expedited prospecting method.

Lyons-Baral said one of the most exciting drone applications he has worked on is in exploration where Hexagon, Headwall Photonics, the University of Arizona and Lisbon Valley mine recently teamed up to investigate the feasibility of drone-based hyperspectral mineral characterisation analysis for mining and exploration.

"This summer, we conducted field work on the Colorado Plateau and the Lisbon Valley mine in eastern Utah, US. Right now, we are analysing the results and they are looking outstanding," he said.

"From natural stratigraphic outcrops, to mining highwalls, to leach pads, we are getting very detailed mineralised zones discretisation."

Clipped wings

For all of the new and expanding applications drones are providing today, there are still certain constraints holding them back from an even wider number.

Regulations associated with the piloting of drones are one such hurdle to overcome.

While Kumba is looking to expand its use of drones into engineering, environmental inspection, plant, real-time mining operations and blast clearance, according to Bester, the company had to go through a lengthy two-year process to earn an operating licence to fly remotely-piloted drones in the Northern Cape.

Bester admitted starting the process with the South African Civil Aviation Authority (SACAA), today, would be much easier, but it all depended on which drone or UAV an operator chose to fly.

"In instances where you choose a unit already included in your operation specifications (meaning it is known to the SACAA), it makes it easier to gain a licence to operate that additional unit.

"If you propose using something new and imported from, say, New Zealand and the authority does not know anything about it, it takes a long time to go through the process," he said.

And, some operators complain about authorities limiting the height drones can fly at, arguing a higher trajectory would allow speedier large-scale surveys.

The process of flying automated drones also comes with regulatory issues.

Operators such as **Airobotics** are offering autonomous drone operations for pre-programmed missions upon take off.

The company recently signed a distribution partnership deal with RockBlast in Chile to allow miners in the country to use its Optimus autonomous drones for volume calculations, terrain mapping, asset management and change detection, among other applications.

But such autonomy is limited to line of sight in some countries such as the US.

Lyons-Baral said: "If the line of sight restriction – having to maintain visual contact with your aircraft – is removed, there could be lots more autonomous missions where drones go out on a timed basis, fly and come back with data and recharge for the next mission," he said.

Storage of the data from drones is also an issue for regular users.

Kumba's Bester said: "You need to decide what area you want to survey and fly it in such a way that you don't overburden yourself with data."

The end result of an increasing use of drones is likely to be cloud-based storage, but not all companies have such infrastructure in place.

Factor in the use of drone swarms – where multiple units will be surveying large areas all at once – and the storage requirements, again, increase.

Going deeper

Most would agree the future destination for drones is underground exploration, monitoring and surveying.

Underground is where these units could provide the most safety benefits, relaying rock stability, gas detection and water level information to those personnel above ground, and Lyons-Baral said there is already major demand.

"We're always getting asked about drones for underground mining. The mines definitely want it and more and more groups are getting into it," he said.

One such group is Sweden-based **Inkonova**, which has developed drones to survey, map and navigate subterranean or constricted zones deemed difficult or impossible with previous technology.

As drones become commonplace, reliable connections to either facilities on the ground or other units are increasingly important.

This is where wireless mesh networks like **Rajant's** Kinetic Mesh® technology is useful.

Kinetic Mesh delivers communication and video backhaul capabilities, and mine site survey applications to strengthen connections, according to Rajant.

One of the first companies to capitalise on these advances – which include broadband-over-VTOL (vertical take-off and landing)-aircraft capable of transmitting applications up to 300 Mb/s – was **xCraft**, a developer of drone technology. The two signed an agreement last year that saw the coupling of Rajant's Kinetic Mesh technology with xCraft's x2i Hybrid VTOL drone, allowing users to fly in single, swarm or tethered configurations, according to Rajant.

Bob Schena, Rajant Chairman and CEO, said the combination allows one pilot to operate many x2i aircraft concurrently, with flight times of 45 minutes. As the craft are equipped with various payloads for video, LiDAR and chemical detection, it opens many new monitoring capabilities.

For those open-pit miners that already have Rajant's flagship connection technology installed, connecting to a drone is a pretty simple process.

Adam Braun, Systems Engineer at Rajant, said in one of the company's recent open-pit mining case study videos: "We're able to utilise the Rajant network already established at the mine to be able to communicate with drones with any sort of sensor data, as well as command and control the drones and see their health while they are in the air."

Steven Griggs, Director of Sales Engineering at Rajant, expanded on this: "The drone would operate on the network like any other node and the aerial platform would simply integrate, and you would be able to monitor the telemetry of the drone."

Normal GPS navigation systems tend to provide an accuracy of between 10 and 30 ft (3-9 m), whereas Rajant's RTK over Kinetic Mesh Network is much more accurate, according to Griggs.

"We can use the data...to get the drone to exactly where it needs to be to the cm," he said.

Inkonova's TILT Ranger drone

Its Batonomous navigation technology and TILT Ranger and TILT Scout drones enable autonomous operation in spaces where all infrastructure (such as GPS, light, beacons, etc) is absent, no prior map exists, and the environment is challenging, the company says. The drones can climb/run/fly using tilt-rotors and a special wheeled design, and are engineered to resist water, dust, and navigate rough terrain underground.

The Batonomous system allows the TILT Ranger or TILT Scout to fly and survey with a click on a screen. It doesn't require manual piloting or GPS, according to Inkonova.

One particularly innovative component is the ability to create its own real-time 3D laser point cloud via various sensors and relay this to a user using Wi-Fi and radio-over-video connection. These sensors allow the drone to 'sense' where it is and create a 'map' as it goes along, thus providing companies with an understanding of uncharted areas.

The TILT Ranger drone, meanwhile, has been developed with space and payload capacity in mind, allowing the unit to navigate through tight spaces with a full 3D Clickmox LiDAR system attached. It also features tilting arms for flight at different body angles or rolling on the ground.

The TILT Scout is a smaller unit for inspection of even tighter spaces like pipes and tanks. It is usually used for lower-risk pre-inspections of underground zones before scans are carried out with the bigger and more expensive Ranger.

After several trials this year, the company secured its first commercial order (CO) from LKAB in April, with the iron ore miner signing up for a scanning mission using the Batonomous system at its Malmberget mine in northern Sweden.

It has since been awarded another CO for the Golden Sunlight mine in Montana, US, an asset owned by Barrick Gold. Ahmed AlNomany, Co-founder and CEO of Inkonova, said the mission, which took place at the end of August, involved use of both the Batonomous system and the TILT Ranger.

The mission was set to access previously inaccessible stopes underground with several technical deliverables including 3D laser point clouds, visual footage and photogrammetry. The mission, funded by Alpha Foundation for the Improvement of Mine Safety and Health, was co-liaised and supported by Montana Tech University as a part of Barrick's Underground Autonomous Drone project.

This is one of a handful of underground projects taking place with drones; the industry can expect many more in the future. IM