

Precise control

Paul Moore spoke to the key firms offering low and high-precision GPS positioning for mines

Global navigation satellite systems (GNSS) provide geo-spatial positioning. Small electronic receivers determine location using time signals transmitted along a line-of-sight by radio from satellites. Receivers calculate the precise time, as well as the position.

The US-owned NAVSTAR global positioning system (GPS) is the only one that is completely operational. Russia's GLONASS is in the process of being restored to full operation, while the EU's Galileo system is in its initial deployment phase and scheduled to be working in 2014.

China has indicated that it will expand its regional Beidou navigation system into the global Compass navigation system by 2020, while India is set to launch its GPS Aided Geo Augmented Navigation (GAGAN) system.

Michael Murphy, global mining technology and autonomy manager at Caterpillar, comments: "With the inclusion of the GLONASS satellite constellation, GPS coverage in the polar extremes of the world has improved. Caterpillar offers, as standard, on its mining technology products GPS receivers, both low and high, that have the capability to utilise both the GLONASS satellite constellation and the L1/L2 satellites. This capability allows most mine sites – except those with very deep pit, high wall conditions – to avoid using ground-based satellites [pseudolites]."

The main providers of actual GPS receivers are NovAtel, Trimble, Topcon and Ashtech. NovAtel is owned by Leica parent Hexagon AB, while Trimble works with Caterpillar through joint venture Caterpillar Trimble Controls Technologies. Topcon works with APS, Modular Mining and others.

The key players in offering complete turnkey HPGPS systems, which include the receiver hardware and software interface, include Leica Geosystems, Wenco, Caterpillar, Modular Mining, APS, Devex and VIST Group.

Carlson will soon join this list.

VIST Group is Russia's leading domestic supplier of fleet management and HPGPS

systems. The fleet system is called Karjer, and the company is contracted by the Russian government for the widespread integration of this technology in Russian mining enterprises. The HPGPS solutions are SkarEx and SkarDrill.

HIGH AND LOW PRECISION

An important distinction that can be made with the use of GPS systems in mines is between low and high precision. Geoff Roberts, sales and marketing executive for mining systems at Leica Geosystems, says: "Low-precision fleet-management ensures machinery is in the right place at the right time. This is especially beneficial for haul trucks, where they can be assigned best path routes to the shovel of most need.

"Low-precision GPS is also available for shovels, dozers, drills and auxiliary vehicles where high-precision machine guidance is not necessary. These systems offer production analysis, proximity awareness and consumable tracking, among other features tailored to the machine.

"High-precision machine control allows shovels, dozers, drills and draglines to carry out a plan to the highest levels of accuracy. The need for staking is eliminated; site plans are downloaded directly to the cabin, which can then be carried out with accuracy within centimetres," he adds.

The work on autonomous equipment in surface mining is also a driver for HPGPS development and usage. Príncipe Jardim, spokesperson for Devex, tells *Mining Magazine*: "In the past, HPGPS advancement has seen improvements in operational efficiencies based on knowing in centimetres, rather than in metres, how accurate the operator has been, thereby improving grade control and understanding how an orebody was mined.

"This is changing, where HPGPS, along with other integrated technologies, is being used to develop a new type of more intelligent mine or 'autonomous mine' where these solutions are being used to develop autonomous trucks, automated blasthole drills, and GPS-guided and computer-controlled dozers and scrapers."

Automated monitoring and reporting systems collect data in real time and use telemetry systems to relay it to the mine management office where it can be used to correlate production, utilisation, mechanical and other data instantly.

Mr Murphy at Caterpillar says: "As the mining industry moves toward autonomous

mining equipment, reliable and consistent GPS coverage will become increasingly important as you must have GPS coverage on a machine or have intelligent on-board systems so that the machine can continue to navigate to its desired location. Caterpillar is at the forefront of utilising improved HPGPS products and alternative navigational systems for the Caterpillar Autonomous Haulage System."

HPGPS TAKE-UP/MARKET TRENDS

In recent years, mining companies have accepted the need to have this type of technology. Mr Roberts at Leica Geosystems, comments: "High-precision machine guidance is now seen as a must have, while in years gone by there were companies who considered machine control as just something that was nice to have.

"The sites adopting the technology have seen material advantages, efficiency and control, as well as the information available for decision making. With demand for commodities high, these sites have a significant competitive advantage."

Fraser Kendall, sales and marketing manager at Australia's APS, comments: "People now have an idea of the technology's meaning. A few years ago, you would need to explain what it is and what it does. The way mining companies interact with HPGPS solutions is also changing. A lot of sites now have some kind of high-precision guidance, driven mainly by safety and productivity."

APS systems can work with any kind of GPS base station, and the data is 'open format', so it can be taken into other reporting packages or mine software. The firm is the preferred supplier to leading Australasian mining contractor Thiess.

In terms of the machines the technology is installed on, this varies by customer and operation, but more recently whole fleets are being equipped.

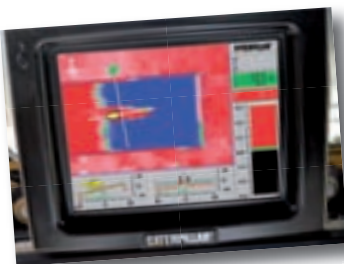
Michael Murphy at Caterpillar states: "It seems that once customers decide to invest in HPGPS technology, most typically outfit the majority of their production mobile equipment – including drills, dozers, shovels and draglines. In the last three years, Caterpillar has also seen a significant increase in customers' use of CAES on shovels. Within the last two years, we have seen an increasing demand from customers to use CAES on auxiliary equipment such as rubber-tyred dozers and motor graders."



Aquila system display on blasthole drill



CAES display for ore control on hydraulic shovel



CAES display on dozer

LINE OF SIGHT

Despite the improved technology of GPS receivers, as well as the new satellites expected to come into operation in the coming years, line-of-sight satellite availability continues to be a significant issue. Mines are going deeper, often in remote regions with difficult terrain that can block satellite signals easily. Accuracy is also downgraded if the geometry of the remaining visible satellites is poor.

Depth and remoteness are not the only issues. The 'lack of satellites' problem also gets worse as pit locations move further north or south of the equator. This is caused by the placement of the orbital planes of the satellite constellations, as the orbits are orientated to cover more populated and 'strategically important' areas, such as areas of military activity.

Nunzio Zambale, CEO of Australia-based Locata Corp, explains: "As pits get deeper, visibility will always suffer because the mine shape creates a cone view of the sky. It is important to understand that for good



Cat GPS antenna

and reliable, high-accuracy positioning, a GPS receiver really should have at least six, but preferably seven or eight, satellites 'in view'. This is not always possible, even in open areas, let alone in a pit. Adding more satellites to the solution will help alleviate the problem somewhat, but it definitely does not solve it."

For several years, Leica Geosystems has offered a hybrid positioning system, which uses both GPS and GLONASS signals. This significantly increases the number of satellites available, providing more options to achieve positioning. But, ultimately, the company sees the answer as making HPGPS systems less dependent on satellites and it has done this by integrating LocataLites from Locata.

Mr Roberts at Leica says: "LocataLites act as ground-based satellites, positioned around the rim of the pit, transmitting to receivers mounted on the machinery. As the pit is dug deeper, positioning using

this technology actually becomes more accurate, as sufficient vertical geometry for 3D positioning is gained. Where there are holes in coverage, LocataLites can easily be moved around site to a position where the signal will not be obstructed. Once positioned, the LocataLite will self-survey, allowing machinery to continue operating with accuracy."

NOVARIANT

The solution for mines has been to use ground-based transmit stations or pseudolites. The established company providing this technology is Novariant, whose system works through installing a network of four or more transmit stations, which it calls 'Terralites', around the rim of the pit.

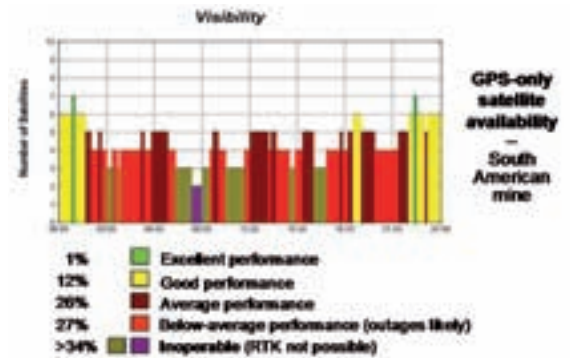
These Terralites broadcast a new positioning signal, called XPS, to mobile receivers mounted on machines. These unique GPS/XPS receivers can process XYZ position data using a combination of GPS and Terralite signals. Terralite XPS can therefore provide accurate data, even with fewer than four satellites in view.

Kurt Zimmerman, CTO and vice-president of emerging business at Novariant, says: "Since we can project the future availability of satellite systems, we don't expect the challenge to go away any time soon. Most importantly, autonomous and life-critical safety systems will increase dependence on positioning technology in the future, causing even the shortest outages to be unacceptable. The ability for the mine to control its operation by assuring positioning coverage and integrity with redundancy will be mission-critical."

Mr Gambale adds: "The worst place for GPS positioning is when machines operate close to pit walls. In such cases there may actually be an adequate number of satellites in view in the centre of the pit. But, when the machine gets close to the pit wall, half of the sky is masked. Our mining partners have examples of pits where satellite-based positioning is considered either 'bad', where outages will occur, or 'inoperable' over 50% of the time."

The Novariant Terralite XPS system has been installed with five of the leading brands of HPGPS applications, and it can operate alongside other positioning systems.

In terms of future improvements, Mr Zimmerman comments: "We've just released our next generation of technology with the ability to track the Russian satellite constellation, GLONASS, in addition to GPS and Terralite XPS tracking. We have also improved the technology to seamlessly cover multiple pit regions with



Graph showing the high variability of satellite availability at a sample mine

our Terralite Network Constellation capability, and have added the capability to add more Terralite transmitters per constellation. All these improvements provide a much more robust solution to the end user, with system flexibility to cover typical pit shapes to very complex, multiple pit operations."

Novariant has experienced average annual growth of about 30% for several years now, including during the global recession. Mr Zimmerman suggests: "We have been able to do this because our system improves operational efficiency and mine productivity. We are established in the largest mines owned by six of the top-ten mining companies by market capitalisation, as well as Codelco. We expect not only repeat business from these top-tier customers, but also new business from medium and smaller mining companies."

LOCATA

The new company providing solutions to satellite availability issues is Locata. Its technology concept differs to Novariant's in that it involves the deployment of a network of ground receivers (LocataLites), which transmit positioning signals to either augment or replace GNSS. These transceivers form a time-synchronous positioning network called a LocataNet, potentially allowing single-point positioning (with no differential correction and data links) with centimetre-level accuracy.

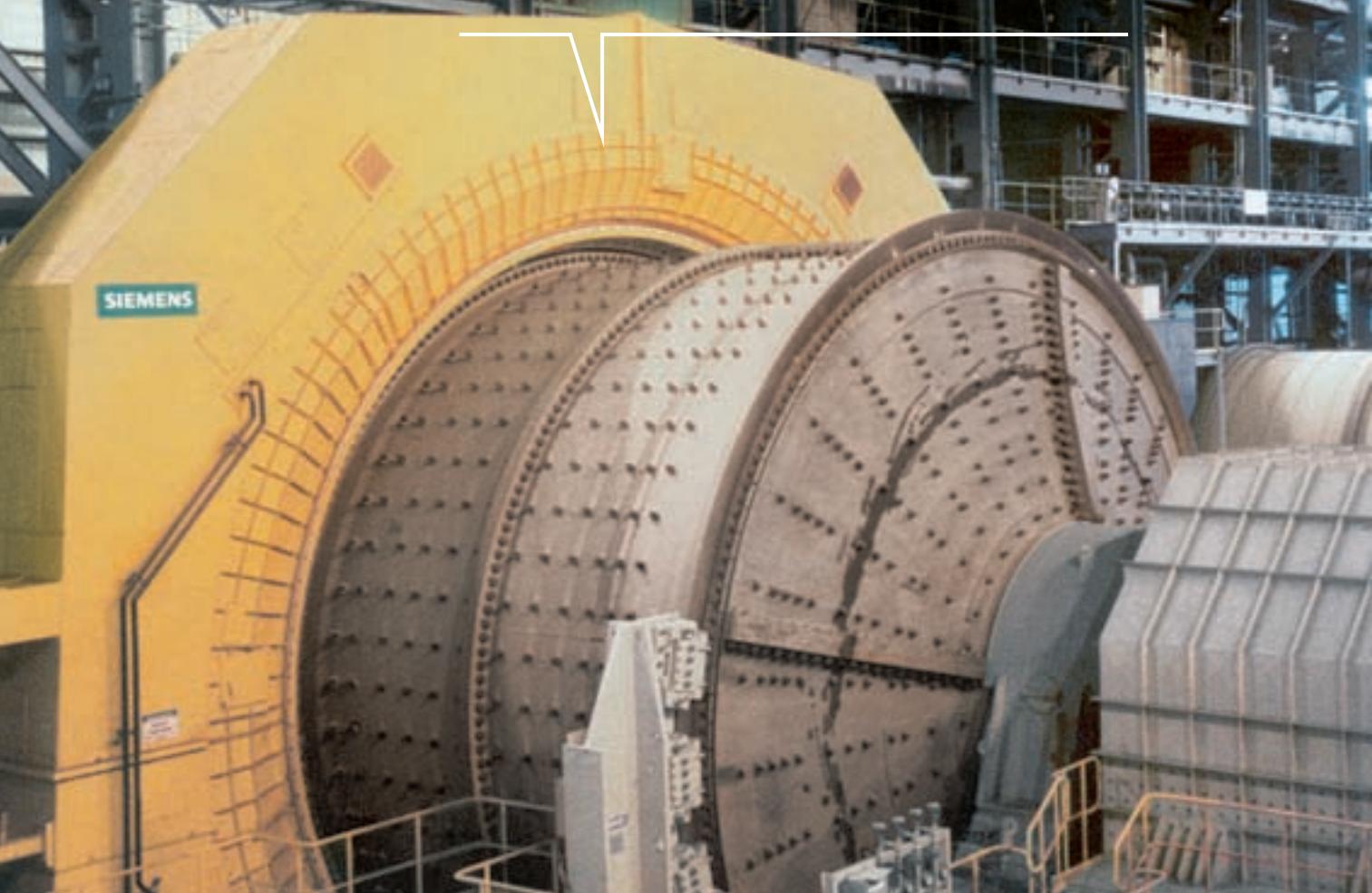
Mr Gambale tells *Mining Magazine*: "Locata has created a local and independent terrestrial replica of GPS. We are the only company in the world that can do this, and we call it 'your own GPS.' Locata is not simply an augmentation to the GPS system, although it certainly does that very well. We have actually invented a world-first way of providing GPS functionality without using any satellites at all. ▶

"Locata has created a local, independent terrestrial replica of GPS. We are the only company in the world that can do this... we call it 'your own GPS' "

FleetCommander display on Cat mining truck



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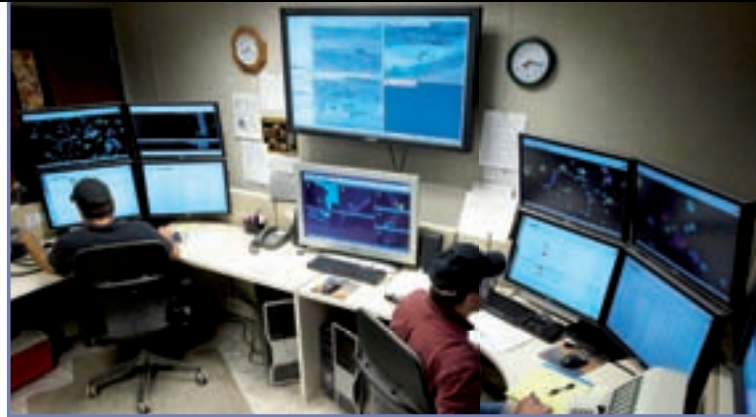
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► “This means we supply survey-grade centimetre-level positioning without needing differential corrections, without needing a reference base station and a communications system, or needing to rely on any other ‘technical crutches.’ Locata is plainly a new way to do GPS-style positioning, and we enable our partners to develop remarkable new capabilities for positioning systems.”

Locata’s exclusive integrator for mining applications is Leica Geosystems, which is rolling out the former’s systems through its Jigsaw fleet management products. Locata’s business plan in the longer term is to be available in the marketplace in exactly the same way as GPS, in that its signal should be available to any integrator that wants to use it.

In March, Leica installed the first operational stage of a full-scale LocataNet deployment at Newmont’s Boddington Gold Mine in Western Australia. The system has been closely monitored since then to compare its performance against a high-performance, survey-grade truth system. The LocataNet is standalone, without any form of external positioning assistance. The results have been very positive and a follow-up article on the project will appear in the next issue of *Mining Magazine*.



Two Cat FleetCommander controllers at stations, Newmont operation

DEVEX

Brazil’s Devex has offered both low and high-precision GPS solutions for a number of years. These have been developed to work on a number of different machines, such as hydraulic excavators and rope shovels, dozers, front-end loaders and hydraulic drills. Devex can also offer products for equipment positioning in underground mines.

The LPGPS fleet-management system is called SmartMine, which has found considerable success in the company’s home market. Currently, in Brazil, 82% of the mines using an automated dispatch system have SmartMine. Over the last three years this has included the following mines: Paragominas (Vale); Onça Puma (Vale); Maracá (Yamana); Rio Paracatu (Kinross); Niquelandia (Votorantim);

Barro Alto (Anglo American); Cana Brava (SAMA); Usiminas, Cajati (Metal Ar), and Usina do Barreiro (Harsco).

In Chile, SmartMine users include the Kinross-owned Maricunga mine.

The HPGPS system is known as Exacta, and became available in 2006, with a Loader version for excavators. Driller and Dozer options appeared in 2007. Currently, the Exacta Loader System is the best-selling package and the one most used by clients.

In Brazil, mine sites have been investing a lot in technology, realising that it is very important to monitor and control the mining operation, and not only mine planning or the processing plant. HPGPS is one of the main topics in this discussion.

Princia Jardim comments: “Sites where the required selectivity of the material is high attach great importance to the Exacta ►

“In Brazil, mine sites have been investing a lot in technology”



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Leica Jigsaw360 screen and computer hub

► Loader System for quality improvements. Sites using strip mining will get great benefits from the Exacta Dozer System, and sites which depend on good blast effectiveness will benefit from the Exacta Drill System. We try to offer a technical solution that fits the mine reality in order to deliver the maximum benefits."

A key user of the Exacta Loader System is Vale's Mineração Onça Puma nickel mine. Nine machines have the system installed – three Caterpillar 988 front-end loaders and six Caterpillar 365 hydraulic excavators. Exacta is required because the nickel-ore extraction is very selective, and any misdirection of material can mean a great loss in stockpile quality.

Exacta helps operators extract the correct ore block. The onboard computer shows the operator the equipment's bucket position with an error of less than 25cm; a precision level measured and proved by the mine's own topographers.

"Leica believes Jigsaw360 is an advance over past fleet-management systems ... dispatching best-path routes to the shovel of most need"

LEICA GEOSYSTEMS

Leica Geosystems has expanded beyond its traditional markets in Australia since 2007. With the acquisition of Jigsaw Technologies in 2007, Leica achieved a significantly larger presence in North and South America. The firm has also entered new markets in Indonesia and India, where its Jigsaw360 fleet-management system has helped to modernise mines and had a great impact on efficiency.

Leica believes Jigsaw360 is an advance over fleet-management systems of the past as the optimisation algorithm used offers a substantial benefit in its ability to avoid queuing at shovels, dispatching best-path routes to the shovel of most need. As part of the Jigsaw360 system, Leica also offers low-precision GPS for shovels and dozers, where their duties do not demand the accuracy of a high-precision system.

Its key HPGPS products are DrillNav Plus, DozerNav JS, DigNav JS and DragNav Plus, all of which provide KPI monitoring/feedback. DrillNav Plus allows drill plans to be designed in the office and downloaded to the machine, eliminating the need for staking. The operator can then carry out the plan accurately, to the correct elevation, resulting in even fragmentation, greatly reducing the cost of blasting. With DozerNav JS, a site design

plan is displayed to drivers, allowing real-time cut/fill grids, cross-section profiles, and plan view and hatch view, without staking.

DigNav JS fully integrates with Jigsaw360. Productivity is optimised through accuracy and the ability to dig to plan. Production is monitored, allowing blending of grades through controlling where the trucks dump. Operator KPIs are monitored, enabling training where necessary, to achieve higher skills across the workforce.

DragNav Plus allows dragline operators to see where the bucket is on the pit design, displayed on screen. Benefits include correct spoil placement and minimised rehandling.

CARLSON

The main Carlson HPGPS-related product is Carlson Grade, a 3D machine-control software, which runs inside dozers, bucket wheels, shovels, draglines, motor graders and scrapers.

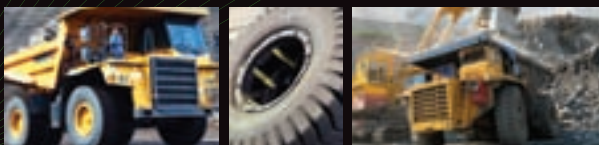
The software gathers the data from the receiver, supplied by Topcon or others, and provides an interface with the machine operator in a graphical form that represents the machine's position. This is used by the operator to make decisions. It provides one consistent user interface,

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allowing each operator to use the same system on different types of equipment.

Also available for mine managers and site inspectors is a version of Carlson Grade that uses Carlson Heartbeat – this provides connectivity between machines, and means that the operators and managers can see where all of the machines are operating and the data from different machines. This also includes elements of machine health monitoring. It also records data from across the fleet, so productivity analyses of both single machines and fleets can be produced.

Where Carlson Grade operates, the company has seen dozers to be by far the largest market due to the sheer number operating, versus shovels and other equipment, especially in coal mines. In coal mines, HPGPS is often used as it allows the operator to differentiate between different grades of coal that have been mapped, but need to be blended as part of the production process. Carlson's first HPGPS site was the Falkirk coal mine in 2001 (see article by dealer RDO on pages 50-51).

Randy Noland, vice-president of positioning and machine control at Carlson, comments: "Carlson believes in open architecture and our software will talk to any receiver. We are unique in this respect in providing a hardware agnostic solution."

At the same time, the company is soon to launch a turnkey GPS solution, but Carlson Grade will not be exclusively tied to it.

CATERPILLAR

Caterpillar supplies the OEM machines themselves, including trucks, dozers and scrapers, in addition to both low and high-precision GPS systems. The LPGPS system is MineStar FleetCommander, and the HPGPS solutions include CAES, Aquila and AccuGrade.

Michael Murphy, global mining technology and autonomy manager, tells *Mining Magazine*: "Because Cat makes both the machine and technology, it allows us to integrate the systems – something no other competitor can effectively do. Probably the best example of this is our VIMS product, which comes as standard on Caterpillar mining trucks and on several other machine models.

"VIMS collects multiple machine parameters in one central, core repository – everything from exhaust temperature to payload – and is built into our machines. With competitive machines, a mining customer has to link their fleet management system to multiple major machine components – engine sensors, transmission, payload and tyres just to name a few." Another example is the recently released Caterpillar Integrated Object Detection System (ODS).

In terms of the actual GPS systems, MineStar FleetCommander incorporates an industry-leading Assignment algorithm, which enables users to use their mobile equipment in the most effective manner. In MineStar 3.0, released in May 2009, the Assignment functionality was improved through tighter integration with the mine model, which enables improved asset utilisation and assignments.

MineStar is built on an open architecture, and has been since its introduction in 2000, which gives it the ability to capture and report on machine data from any machine from any manufacturer, as long as the on-board protocol links are obtained.

The Caterpillar CAES and Aquila HPGPS systems can bring as much as 25% productivity improvements, according to the company. This can be achieved through a variety of ways, including reducing the amount of rework by ensuring the right material is moved correctly the first time, improving the accuracy and efficiency of drills by putting the design file in the cab, nearly eliminating all drill staking work, and improving ore control by material tracking through CAES.

CAES is an industry leader in ore identification and material tracking. This capability allows the mine to provide the operator with the precise grade of ore that is being dug via an in-cab display, which results in improved ore-quality accuracy, and less material dilution and misdirected loads.

For the Aquila Drill Systems, Caterpillar is nearing the commercial release of the system on articulated or boom-type drills. This is in direct response to customers, who extensively use the system on downhole rotary drills. This new system gives mining customers a common system across their drill fleet, with similar capabilities, all working

from the same fundamental software to increase drill-hole

accuracy, position and depth.

WENCO

Wenco offers its well known Fleet Management System and HPGPS BenchManager products. In terms of the LPGPS fleet solutions, Glen Trainor, director of marketing and North American sales at Wenco, comments: "Functionality and benefits have long surpassed the provision of assignments to haul trucks. Although this productivity management is still at the core of the system, the benefits that extend from that core are far reaching.

"These systems are still referenced as GPS-based systems and, although this is true and GPS does provide us with the core information of location and velocity, the systems become effective because of the way the GPS information is used by the vendor and integrated with other inputs."

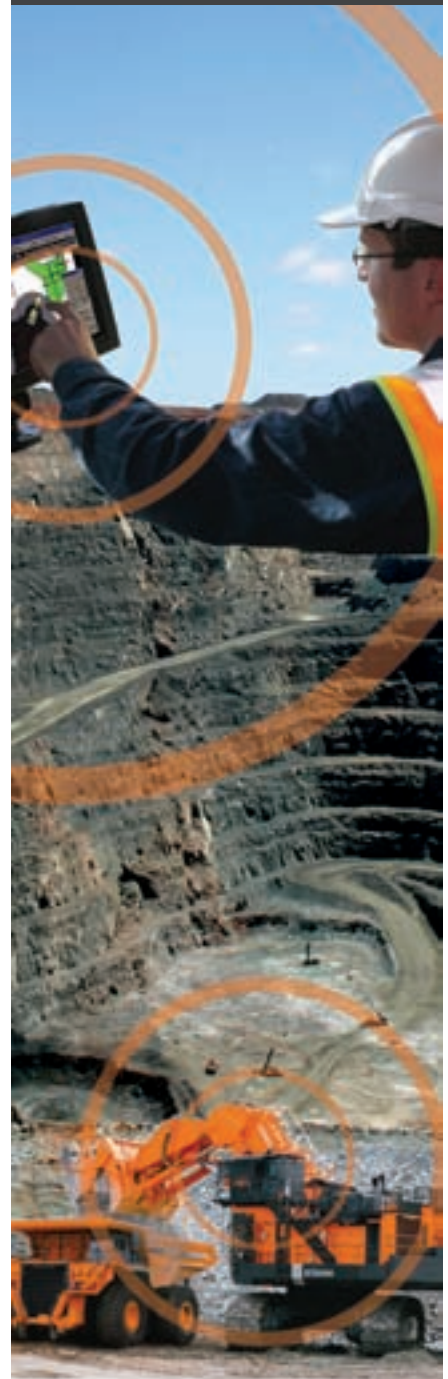
Advancement then comes from two main sources: technological advances and the developer's ability to integrate all of the inputs in the most effective way. With improvements in wireless broadband communications in the mobile and rugged environments, more data can be transmitted and many mines are doing their best to take advantage of this. ▶



Topcon GPS receiver, supplied by RDO



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Leica's Jigsaw360 can help users avoid trucks queuing at shovels

“Modular HPGPS machine guidance systems, such as ProVision, reduce reworking while dramatically reducing survey costs”

► Wenco HPGPS systems are intended to be fully integrated with its fleet-management system. BenchManager sales have been closely tied with Wenco's fleet-management installations, which are continuing to gain new market share. The integration includes the ability for the BenchManager and Fleet Management software to operate simultaneously on the same on-board computer, using the same screen.

A key attribute is the ability to accept external inputs, whether digital or via serial interface, which gives the BenchManager system more data to offer more functionality, and greater accuracy in reporting. An example could be digital inputs to indicate whether a dozer ripper is engaged and over what distance, or interface to OEM machines for engine monitoring.

Two recent installations implemented BenchManager, along with the standard system: Canadian Natural Resources (CNRL) in the Alberta oil sands has installed BenchManager on five dozers and five shovels, while Vasilkovsky has installed it on two Komatsu PC1800 hydraulic excavators at a Kazakhstan gold mine.

MODULAR MINING

Modular Mining Systems offers LPGPS (Dispatch) and HPGPS (ProVision) products. In the HPGPS market, Modular sees the



total number of installed systems as being highest for shovels. However, if looking at the percentage of installed systems as a function of the total available fleet, drills are the highest.

Modular regards its Dispatch optimisation algorithm as the gold standard in the industry when it comes to delivering equipment capacity. The company has worked on the NextGen platform to improve usability for the operator and dispatcher. An enterprise reporting platform has also been developed, which delivers information to users via standard, off-the-shelf software.

In terms of LPGPS advantages using Dispatch, Greg Lanz, manager, sales and marketing services, at Modular comments: “Constant and precise location availability enables haulage optimisation and timely rerouting of equipment, which consequently

improves productivity. We also use GPS to increase the situational awareness of the equipment operator and promote informed decisions.”

Many features and functionality have been added in recent years, although they were enabled, not driven, by GPS technology. Wireless communication technology has been the driver for advancements in areas such as proximity detection. The RoadMap system uses LPGPS to manage light vehicles on a mine site.

Modular HPGPS machine guidance systems, such as ProVision, reduce reworking while dramatically reducing survey costs, and eliminate costly delays associated with communicating mine-plan updates to the field.

In addressing the satellite issue, Mr Lanz says: “We recently increased system availability by up to 5% in co-operation with our GPS partner, Topcon. Poor satellite availability has been improved by Russia after it rescued its deteriorating GLONASS system, and the future looks even brighter with other new satellite networks coming online. We have also developed an interface with Novariant to provide a land-based, augmented GPS solution in areas with very poor satellite availability.” ♥

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