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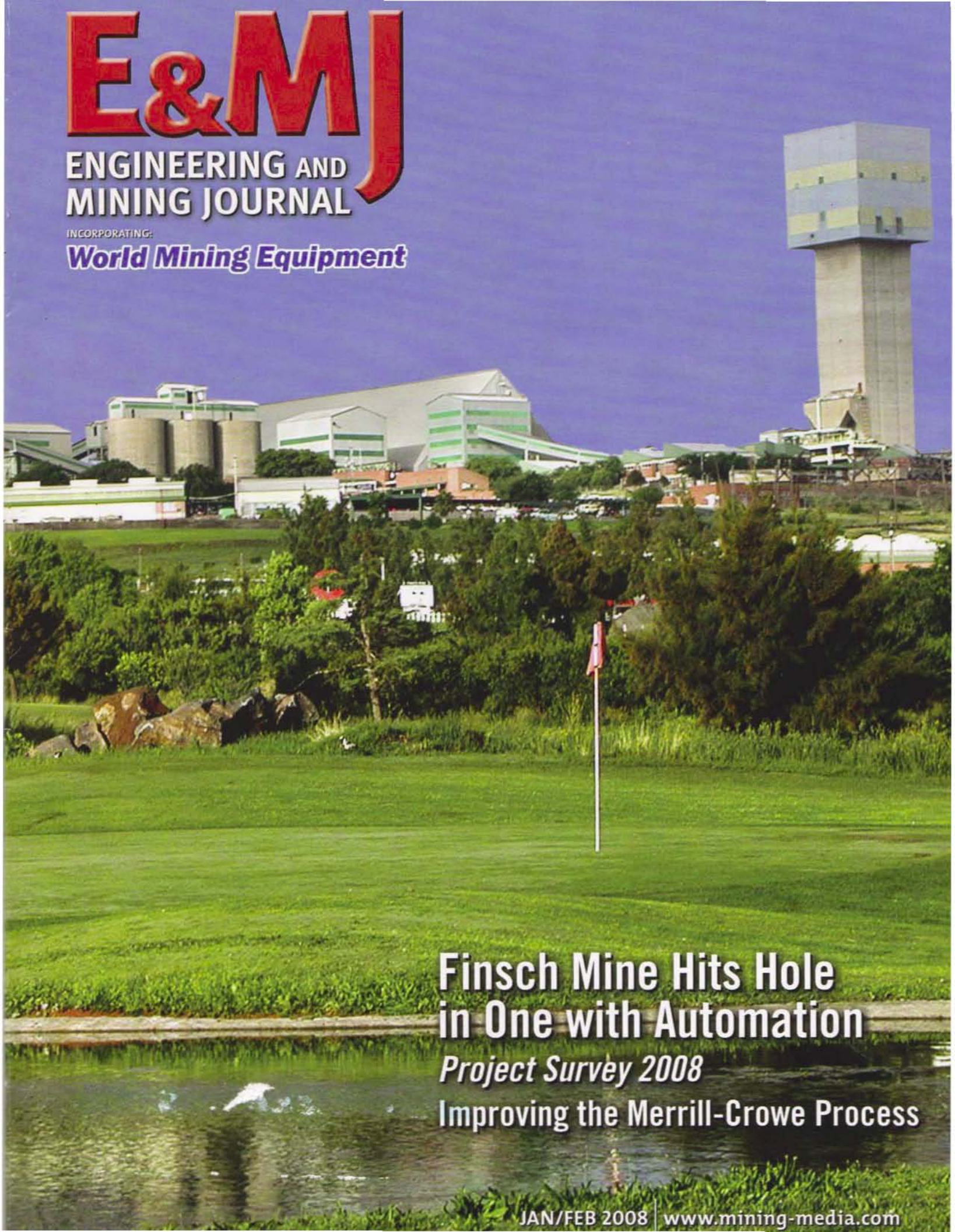

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Location, Location, Location

The steadily improving performance of GPS machine location and guidance systems means that production equipment can run—with greater precision and productivity—but it can't hide

Russell A. Carter, Managing Editor

Perhaps the best indication of how widely a specific technology has been accepted by an industry is the amount of "wow" factor a new announcement must pack in order to make people stop and think about where that technology has come from, and where it's going.

That appears to be the case with GPS-assisted location and guidance of mining equipment, a technology sector that has had its moments in the trade press as various projects and products were announced, often with great fanfare, and then receded into the background after either being gradually assimilated into general industry practices—or quietly moved to the back burner by their sponsors.

From the large to the small: High-precision GPS technology plays a role in both these Komatsu 930E-4 haul trucks, configured for autonomous operation at Rio Tinto's Australian iron ore mines; and in MineMapper, a system that combines laser scanning with GPS location that can be mounted on almost any vehicle to generate highly accurate terrain measurements while on the move.

Starting in the mid-1990s with Caterpillar's initial development of its Computer Aided Earthmoving System (CAES) and Komatsu's purchase of a controlling interest in Modular Mining Systems, which at the time was focused on refining its system for real-time haulage fleet dispatching, the industry has seen—and widely adopted—a steady progression of technological advances that have improved the accuracy, reliability and scope of GPS location and guidance. It's no longer a novelty during mine visits to encounter a truck, shovel, drill or dragline equipped with some type of GPS location/guidance system from Caterpillar, Komatsu, Wenco, Leica Geosystems or Novariant, for example, and recent developments have generally been evolutionary rather than revolutionary.

That attitude of casual acceptance may be jangled a bit, however, with the recent announcement by Rio Tinto that it will take delivery of a fleet of haul trucks from Komatsu that will be configured to operate autonomously in the company's Pilbara iron ore mines in Australia. The autonomous haulage fleet will be just one of several technologies intended to implement automated mine-to-port operations envisaged by Rio Tinto, which will also include driverless trains that will carry ore over 1,200 km of track, remotely controlled drills, and overall mining activity managed from a control center hundreds of miles away from the mine sites.

In mid-January, Rio Tinto's Chief Executive, Tom Albanese, unveiled his company's vision of the mine of the future, describing the initiative as "part of Rio Tinto's drive to maintain its position as Australia's leading iron ore producer." According to Albanese, Rio Tinto intends to be the leader in integrated and automated mining and transport in the Pilbara iron ore region, leading to greater efficiency, lower production costs and more attractive working conditions that will help it to recruit and retain staff in the highly competitive labor market.

Albanese said major components of the autonomous mining plan will be commissioned in Rio Tinto Iron Ore operations in 2008 and 2009, including establishing a remote operations center (ROC) to manage operations in the Pilbara mines. The ROC will allow operators overseeing the company's mines and process plant facilities to be physically located in Perth.

Albanese said, "Rio Tinto is changing the face of mining. We have at least a three-year start on the rest of the industry, which has focused on discrete technologies rather than modernizing the whole mine-to-port operation. We're aim-

ing to be the global leaders in fully integrated, automated operations. It will allow for more efficient operations and directly confront the escalating costs associated with basing employees at remote sites, giving us a competitive advantage as an employer along the way."

Other mining executives may find Albanese's statement debatable, but the company has introduced a number of key technologies on a staged basis to support this scenario, beginning in 2006 with the development of autonomous drilling rigs for the Pilbara. In early 2007, Rio Tinto established and funded the Rio Tinto Center for Mine Automation in partnership with The University of Sydney. Under this partnership Rio Tinto secured exclusive access to robotics experts to address its mine of the future opportunities.

During a media tour of the company's Pilbara operations in January, Greg Lilleyman, general manager East Pilbara operations–iron ore, noted that Rio Tinto had created a technology test hub at its West Angelas mine for centralized testing of autonomous trucks, drills, other equipment and remote operations and planning systems.

Trials will include the Komatsu autonomous haul trucks and a range of other advanced remote control and autonomous technologies. Experience gained there, according to the company, will allow for further deployments in the Pilbara in 2010 and will also have application at other Rio Tinto mining operations.

Komatsu America's manufacturing facility in Peoria, Illinois, USA, will produce the 320-ton-capacity 930E-4 electric drive trucks equipped with the FrontRunner Autonomous Haulage System, a navigation system developed by parent company Komatsu Ltd. and integrated by Modular Mining Systems Inc. Although Komatsu America did not disclose details of the truck order from Rio Tinto, it is thought to involve initial delivery of five or six 930E-4s during 2008. Komatsu previously supplied a fleet of FrontRunner-equipped 930E-4s to Codelco in Chile.

Rio Tinto said the automated haulage system will be commissioned before the end of 2008 and is expected to be more widely deployed by 2010. According to Albanese, the implementation will likely occur first at the company's newer mines constructed as part of its current expansion plans.

The company said studies are also being finalized on the application of autonomous train operations technology in a heavy haul capacity. Mainline trials conducted with the Western Australia Office of Rail Safety have progressed well and a decision on the next stage of the project is expected in mid-2008. Automated rail management is the first major operation scheduled to be run from the ROC.

The East Pilbara ROC will be built for Rio Tinto near Perth's domestic airport. When completed in 2009, the facility will be staffed by more than 300 employees who will work with Pilbara-based personnel to manage and operate key assets and processes, including all mines, processing plants, the rail network, ports and power plants. Operational planning and scheduling functions will also be based in the ROC.

Remote operation of Rio Tinto's mines and plant in the Pilbara has already been successfully trialed, and the company recently began operating the processing plants for its West Angelas and Hope Downs mines from a site in Perth.

One of Many

GPS-assisted machine location and guidance will be just one of many technologies implemented in Rio Tinto's ambitious autonomous mining scenario, but it will be an important element and its inclusion illustrates the high degree of sophistication achieved in this area. Although only a handful of mining companies have the money, technical resources and property assets that could justify autonomous mining of the scope envisaged by Rio Tinto's plans, the range of products available in this sector allows smaller producers to take advantage of GPS services to reduce mining costs, increase productivity and improve both human and machine safety.

Undoubtedly the Rio Tinto announcement will draw renewed attention to the current state of GPS technology as it applies to mine operations, but as far as several key suppliers are concerned, buyer interest is already at a high level. For example, Novariant, a Fremont, California-based supplier of precision positioning systems, recorded first-half 2007 revenues more than 50% higher than the same period a year earlier, and now has systems installed at sites in Arizona (Freeport MacMoRan's Morenci mine), Utah (Rio Tinto's Bingham Canyon mine), Australia (KCGM), and South America (Los Pelambres and Los Bronces—including the recently approved Los Bronces Development Project expansion which is expected to make the Chilean copper mine one of the largest producers in the world).

Kurt Zimmerman, technology manager for Novariant's mining group, said that Novariant is focusing on optimizing the performance of its Terralite XPS positioning system in complex or oddly shaped pits, particularly with regard to increased pit depth and "shadowed" corners of the mine. "Customers are asking us to enhance the effectiveness of our system to meet the specific conditions of their operations, mainly for high-precision applications such as drills, dozers and shovels. But we're also seeing customer interest expanding beyond these typical applications to other types of mine equipment that traditionally haven't required high precision, such as haul trucks. Basically, when the availability of the equipment requiring high-precision location improves, it often opens up other [GPS-related] possibilities for improving mine operations."

Novariant's Terralite XPS System uses a network of ground-based transmitter stations to broadcast a proprietary XPS signal to one or more mobile GPS+XPS receivers, allowing operators of GPS-enabled machines to receive continuous real-time positioning information in locations and under conditions in which conventional GPS information may be unavailable.

Hexagon, the Swedish parent company of Leica Geosystems, advanced its market presence by acquiring Jigsaw Technologies last year. Jigsaw produces fleet management software, with sales estimated at $9 million for 2007. Leica Geosystems' products have sold well in South America—last year, for example, Leica Geosystems Mining supplied seven precision navigation and monitoring drill systems to Newmont's Minera Yanacocha mine in Peru—as well as in Australia and Southeast Asia, and Hexagon bought Tucson, Arizona-based Jigsaw to bolster its sales in North America. At the time of the acquisition announcement in mid-2007, Hexagon estimated the overall market for machine control was growing at a rate of 25% annually, with global sales exceeding $850 million, driven

mainly by demand in the mining, construction and agriculture industries.

The role of precision GPS location and guidance in autonomous mining is clearly illustrated in a current project conducted by Freeport McMoRan's Mining Technology Group in North America. The project, known as Ardvarc and involving Flanders Electric for their control system expertise, is aimed at developing a fully autonomous blasthole drill. Ardvarc is a tracked rotary rig that can tram, set up, sink a hole with high precision and move on to the next position while keeping track of what's happening in its proximity, all without need of human guidance. Ardvarc uses both orbital GPS and ground-based location and guidance systems such as Novariant's for highly accurate positioning, but Steve Williamson of the technology group stressed that the success of projects such as Ardvarc depends on integration of many different systems, including wireless communications, navigation, proximity sensing, day and night vision, machine health and diagnostics, and data collection and reporting, among others.

The control system for the drill was assembled using commercial, off-the-shelf components, said Williamson, who cautioned that even though technology is now readily available to accomplish projects such as Ardvarc, the employees who will use or work around these machines, and even the personnel who have to maintain them, may not initially fully understand or even accept the concepts behind the application. "This is a process that has to extend from the general managers down to the workers in the mine," said Williamson. "People need to buy into a technology—to take ownership of it—before it can be considered a success."

The Ardvarc drill was being tested in December with an operator onboard simply as a safety backup, Williamson explained, but the company expects to move forward with tests involving fully autonomous operation in 2008. Once proven, the system will be applied to other rigs—all Atlas Copco Model 271 Pit Vipers—at the Morenci and Safford mines. The project also has drawn a high level of interest from the company's Grasberg operation in Indonesia, he noted.

Building from Basic to Ultra

Caterpillar, which was an early entrant in the market with its CAES, has steadily upgraded the system's capabilities; the current flagship version, CAES*ultra*, is capable of utilizing both the GPS and GNSS (Global Navigation Satellite System) systems, and can also use Novariant's Terralite XPS positioning solution. CAES*basic* provides CAES's onboard computing power without a wireless link or CAES*ultra's* suite of office software. CAES*basic*-equipped machines can be upgraded to higher functionality by adding a few additional hardware components.

Caterpillar estimates that users can raise productivity in specific areas by an average of 25% using CAES*ultra*, taking into account reduced rework requirements, higher ore recovery rates, reduction or elimination of surveying costs and other factors.

The system now requires only three onboard components: the display unit, an "all in one" receiver/antenna, and radio. The MS990 GNSS receiver offers better performance than previous receivers, according to Cat, and initializes much faster than earlier models. Cat's TC900C radio is now an optional component if a customer is using CAES version 3.1 software, which enables mines to use an IP radio network of their choice; they can tie

in CAES-equipped machines to their existing network by connecting the IP radio to the onboard display through a ruggedized Ethernet port on the back of the display.

Another function enabled by version 3.1 software is peer-to-peer communications, which allows multiple machines to "see" each other in real time, a valuable feature when working at night, during inclement weather or in the vicinity of blind spots.

Cat also offers the Aquila Drill Monitoring system, in three versions: *Basic* is primarily reserved for OEM sales to drill manufacturers and can capture hole depth, penetration rate and rotary speed information. *Production* is the normal base system for customer purchase. It builds on *Basic* by adding wireless communication and increased reporting capabilities. It displays and records six drill variables, including depth and penetration rate, rotary speed, pulldown pressure, bailing air pressure and rotary torque. The third version, *Strata*, adds the ability to associate a blastability index to each hole drilled. This feature, when integrated with local geological information, helps to reduce the use of premium grade explosives to only those areas that warrant the added expense.

Cat says the Aquila GPS guidance option provides the ability to locate the drill bit within three dimensions with accuracy to ±10 cm of the known location. The system automatically adjusts the hole depths based on the zed elevation, measured from the tracks of the drill, ensuring that the rig is drilling to the designed target elevation. The system is applicable to both vertical and incline drill rigs.

Back to the Future?

GPS technology, which started out "small" in mining with the introduction of backpack-transportable surveying units in the early 1990s, has executed almost a complete development cycle as it has filtered back down into smaller equipment categories after reaching the top, so to speak, with its inclusion on the industry's largest equipment. In addition to fitting its largest mining trucks for GPS assisted autonomous mining, Komatsu, for example, now equips its construction-class vehicles with Komtrax, a satellite-assisted machine status and location system that employs GPS technology to keep track of a machine's location.

Elsewhere, U.K.-based 3D Laser Mapping announced that it has developed a mining version of its StreetMapper system. MineMapper uses mobile laser scanning technology combined with high precision positioning systems to capture accurate and detailed measurements while on the move.

MineMapper comprises a set of vehicle-mounted laser scanning units together with an onboard positioning system that uses GPS information and inertial navigation. Each scanner transmits an optical pulse from a known position and at a known direction and angle and records the time taken for the beam to be bounced back to the receiving unit. The speed of light is then used to calculate the exact position of the feature from the laser unit. The system is claimed to be capable of capturing up to 40,000 measurements per second with a typical accuracy of 3- to 5-cm, and can be deployed on a range of vehicles to suit all terrains. When combined with 3D Laser Mapping's SiteMonitor software it can create detailed 3D models of a mining operation for depletion surveys, slope stability models, stockpile measurements and terrain map updates.