IMPROVING PRODUCTIVITY THROUGH TECHNOLOGY INTEGRATION

MINERS SPEAK WITH ONE VOICE ON EQUIPMENT SAFETY

POWER—A driving force at Drummond’s Mina Pribbenow

Automation keeping underground workers safe

at LKAB Malmberget mine

COMMITTED TO SAFETY AND SUSTAINABILITY
Welcome to another edition of Viewpoint—a magazine that gives Caterpillar the opportunity to address the topics that are important to our customers in the mining industry.

As always, we focus on safety—introducing readers to a unique partnership called the Earth Moving Equipment Safety Round Table. This group was formed by eight major mining companies to influence manufacturers to improve equipment design in order to minimize health and safety risks.

We showcase two mines—one underground and one surface—that have implemented technologies that not only improve productivity but also keep people safer on site. LKAB uses MINEGEM™ technology to keep workers out of harm’s way in its underground Malmberget mine. Newmont Mining takes advantage of the many safety and productivity features integrated into MineStar® at its Nevada operations.

This issue’s industry article looks at the challenges mine sites face in finding clean, reliable power. We profile Drummond’s Mina Pribbenow open-pit coal mine, a major Colombian site that uses Caterpillar electric power generator sets to support its operations.

Our product support topic in this issue is maintenance metrics—highlighting the importance of not only doing proper maintenance and repair, but also using metrics to measure the performance of these tasks.

You’ll also find more information on “Managing a Mining Lifestyle,” a DVD previewed in the last issue of Viewpoint. It provides practical solutions to help machine operators and their families cope with the lifestyle required of those in the mining industry.

Please continue to share your feedback so we can make Viewpoint a useful tool for you and the mining industry.

Chris Curfman
PRESIDENT, CATERPILLAR GLOBAL MINING
Mining companies are always on the lookout for ways to improve safety, lower costs, improve profitability and boost efficiency. They adopt preventive maintenance procedures to increase equipment availability and extend machine life. And they seek technologies to increase production, improve ore recovery and keep workers safe.

The application of new technologies continues to have a positive impact on mining operations around the world. Monitoring, diagnostics and prognostics technologies track information on a number of machine functions. Machine guidance systems deliver real-time production information to both machine operators and personnel in the mine office.

A number of mines around the world are using another innovation—Caterpillar’s MineStar™—to integrate these existing technologies and add additional capabilities that improve their overall operations. MineStar is a comprehensive system that links machine data gathered in the field, and existing ore control and material identification information, to the office business enterprise systems.

Integrated information systems allow mines to make improvements across the entire site—in operations, maintenance, safety and mine management.

“It can make the whole operation more productive,” says Ken Edwards, a Caterpillar marketing division manager. “On average, mining companies are reporting efficiency improvements of 10 to 20 percent.”
One company that has embraced the technology is world-leading gold producer Newmont, which worked side-by-side with Caterpillar and dealer Cashman Equipment Co. to implement a customized MineStar application for its North American operations in Nevada, USA.

“Newmont wanted a monitoring and control system to optimally assign trucks, control complex materials, manage daily operations and impact efficiency and productivity,” says Michael Murphy, commercial manager of Caterpillar Mining Technology. “And that’s what MineStar’s Fleet Commander component does.”

In order to meet Newmont’s needs, the two companies worked together to create an industry leading solution. The system covers multiple sites with a full range of technology for blasthole drills, track-type tractors, loading tools and the haulage fleet. Caterpillar even developed software to manage the mine’s overhead loading facility.

“We’re continuing to work closely with Newmont to take the system to the next level,” says Murphy. “The site has experienced production improvements with us working together as a team.”

Newmont faces a host of mining challenges in its complex Nevada operations. Newmont owns or controls about 7,915 square kilometers (3,056 square miles) of land stretching across the state. The company operates a large number of machines in a variety of sizes, sometimes trucking ore 161 kilometers (100 miles). In addition, Newmont has some of the most complex ore bodies in the world. A typical mine site has less than a dozen types of ore; Newmont’s Nevada operations have up to 100.

With so many different variables in play, driving toward a culture of similar metrics helps Newmont achieve the most efficient production possible. MineStar is one tool making it possible for Newmont to achieve that similarity by providing consistent
processes and reporting across three different sites at the same time.

GETTING A BETTER VIEW

The amount of information MineStar provides, plus the fact that the software is managing activities on the site, have significantly changed the role of Newmont’s Daniel Reilly, a lead dispatcher. He has an overall view of every machine working on the site.

“Looking at the computer screens, I can tell if the trucks are loaded or empty, what they are loaded with, what kind of material they’re hauling and where they’re going. I know the fuel quantity on machines, I know how many loads they’ve hauled today, if there have been delays, if a machine has broken down or if the operator is taking a break.”

IMPROVING PRODUCTIVITY THROUGH EFFICIENCY

The MineStar system has played a big role in making Newmont’s Nevada operations more efficient, according to Steve Micheli, Newmont’s MineStar foreman. “Prior to MineStar, we had inefficiencies,” says Micheli. “More was done manually by a controller. Now the computer does the calculations and we can just turn the trucks loose. The system is working two loads ahead of where the truck needs to be.”

“In a 12-hour shift, we may get between 13 to 15 extra loads per shift by running free assignment,” he continues. “And it takes six to seven passes to load one of our Caterpillar 793D trucks. MineStar puts efficiency in the pit, and assigns the trucks to travel the absolute minimum to get the maximum tonnage hauled. We get the most tons we can into a 12-hour shift.”

Micheli says MineStar has increased production by freely assigning trucks and not leaving it up to the human element. “The computer provides accuracy and consistency that humans can’t. And you have to maximize production to be on the winning end of mining.”

“Before, more was done manually by a controller. Now the computer does the calculations and we can just turn the trucks loose. The system is working two loads ahead of where the truck needs to be.” —STEVE MICHELI, NEWMONT’S MINESTAR FOREMAN
“They use the information to change procedures and look at Continuous Improvement projects,” he says. “The system measures everything and it is delivered in user-friendly reports using familiar software like Oracle and Business Objects.” The controllers in the office receive real time Key Performance Indicators (KPIs), which are also available on board the machine for the operator.

**IMPROVING ORE CLASSIFICATION AND RECOVERY**

One of the most positive outcomes from the MineStar implementation at Newmont has been the ability to track the many types of ore on site. Using high-precision Computer Aided Earthmoving System (CAES) on loading tools, Newmont’s operators can identify the types of ore and create mine models and maps. MineStar uses that information to schedule trucks and loaders to meet the daily goals.

“CAES identifies the type of material and maps the type of the ore at the face. This allows the shovel operator to extract low, medium or high depending on the site’s requirements,” says Murphy. “Then MineStar Fleet Commander tracks, monitors and maximizes the efficiency of how that ore is transported to processing facilities.”

Micheli is responsible for making sure the mine modeling is up-to-date with the pits in the field. “MineStar tracks grade blocks and different types of material so we keep all material where it needs to be,” says Micheli. “It determines what material the loader is digging and makes assignments based on the material type loaded and destinations that accept it.”

“More than anything, we appreciate that we rarely have misplaced loads,” says Micheli. “One load is a lot of money.”

**TAking CARE of MACHInes**

Another key benefit of the MineStar system is MineStar Health, which collects raw data off the machine, transmits it to a server, and allows it to be analyzed using VIMS software.

“Machine Health is increasingly important to the mine operator,” says Edwards. “It allows the sites to see—and our dealers to track—machine health. Machines are going to go down for maintenance issues. And when you’re monitoring them, you’re able to make repairs before a major component failure. It will be much less expensive. Mines can save hundreds of thousands of dollars with preventive maintenance.”

Reilly calls MineStar another tool to help keep the Newmont fleet healthy. “In dispatch, we coordinate with the shop for equipment problems and make sure equipment goes in for regularly scheduled maintenance,” he says. “The maintenance shop works with us on trying to keep things running.”

**IMPROVING SAFETY**

Included in MineStar are a number of features that help improve safety to operators and others on site. For example, the system can be set up to require an operator to punch in a code that will allow him to operate a particular piece of equipment only if he is certified to do so. Once he has been approved for a machine, the operator follows an electronic checklist that must be completed before he can begin work.

An onboard display contains a number of safety features. It can be programmed to transmit regular safety messages, notify operators of machine problems, and inform them about existing or new hazards on site. It also has a moving map on the GPS screen that shows the operator the haul road, dump and loading tool directions.
COUNTING ON CATERPILLAR

Newmont operates a fleet of all Cat® trucks and support equipment, along with the Cat 994 loader as the wheel loader component of its loading fleet. Because of that consistency, the implementation of MineStar allows better integration into the machine data.

“We revamped our Cat fleet in the past two years,” says Jack Henris, surface mine manager. “We went with Cat because of the reliability of the machines, and outstanding support from our dealer, Cashman.”

Edwards explains that the dealer supports not only the machine and MineStar components, but the onboard GPS and radio system as well. “Having a one-source provider is very important,” he says. “It allows the company to minimize the number of suppliers on site.”

CALCULATING THE BENEFITS

MineStar can be a good solution for mines of all sizes in every environment. “Some mines think they are too small for this and the expense doesn’t justify it,” says Edwards. “But as the mine grows, getting up to 20 trucks, they quickly realize what a difference a productivity improvement of 10-plus percent makes. You have to have more control when you have more trucks and drills.”

“The system can pay for itself quickly with the price commodities the way they are today,” he says. “During this mining boom, it’s all about getting the ore out of the ground, turning it into a product and shipping it. Production is king. You want to sell every ounce you can while the price is high.”

But Edwards says MineStar may prove even more valuable when the boom ends. “During the next downturn, it will be all about efficiencies—saving every penny and mining efficiently. This software really provides a benefit because the mine can operate much more efficiently and lower cost per ton.”

BUILDING SUSTAINABILITY

Newmont believes that using tools like MineStar to create more efficient operations helps the mine have less of an impact on the environment, and leads to a more sustainable operation.

“In this day and age, mining is necessary to get us the commodities and raw materials we need to keep the world running,” says Randy Walund, mine superintendent. “But the reality is, mining does have an impact on our communities and on the earth. When you are able to use less fossil fuel and less equipment, you are able to lessen that impact.”

“But because we’re able to track materials, the ore that bears the gold goes to the right place and the waste goes to the right place,” he continues. “So we only burn energy in our milling and processing plants that needs to be used. We know we’re putting the right material through processing. We’re not putting waste through. If you send waste to a processing plant, you’re burning energy and using resources that are not required.”

These efficiencies make it easier for Newmont to operate in a high-cost market. “Any time we can improve efficiency, we will sustain our company,” Walund says. “Even though gold prices are high, the cost of everything else is high, too. When we can keep our costs down, it is easier to do business. By doing all these things, we can continue to mine in the future.”

1/ A computerized display helps the operator manage an Aquila drill at Newmont’s Carlin, Nevada, operation.
2/ Caterpillar dealer Cashman Equipment Company is on-site at Newmont’s Nevada operation, putting together a new 994F wheel loader.
3/ This newly assembled 854G wheel dozer is equipped with High Precision GPS.
4/ GPS components on the 994F wheel loader include a GPS antenna and Tremble radio.
What is Minestar?

MineStar has several components. FleetCommander is a comprehensive mine monitoring and control system that tracks assets, maximizes machine utilization and improves productivity and ore recovery. MineStar Health provides actionable information about the condition of a fleet of mining equipment.

These systems can be developed to meet the functionality required by a specific user. A typical implementation includes a radio and GPS system on each truck, a computer display in the cab for the operator, and software that runs in the control room. The controller uses a number of parameters and a number of sources—like information from VIMS and CAES—to manage the mining activities from a remote location.

Michael Murphy, commercial manager of Caterpillar Mining Technology Systems, compares the controller to an orchestra conductor directing a group of musicians, or an air traffic controller managing a crowded airspace.

“The controller sits in a room in front of a computer screen and can see what’s going on with all the trucks on site,” Murphy says.

But MineStar is much more than a remote operations device; it’s a truck assignment tool. Trucks are traveling and loaders operating based on an assignment from the MineStar system. By using parameters input by the controller, MineStar will decide what materials are needed to meet the day’s production targets and where that ore is located, and will send trucks to the appropriate shovels to meet those targets. It will also readjust by looking at shovels and rerouting trucks to other locations to avoid truck queuing.

Before trucks get low on fuel, the MineStar system will begin allocating them to be fueled to maximize production. For Newmont Nevada, shift change has been automated to allow the mine to optimize production for the hours at the end and at the beginning of the shift.

Fleet Commander allows production reporting, truck assignment, health monitoring and fleet analysis.

MineStar Fleet Commander has four main components:

- **MineStar Production**—provides real-time visibility of loading performance, delivers improved shovel loading performance and increases payload predictability.
- **MineStar Material Tracking**—monitors material movement and type, alerts operators and planners of mis-routes to ensure material is moved to the proper location.
- **MineStar Machine Tracking**—monitors machine location for the entire fleet and incorporates playback function to analyze dump movement and haul road congestion.
- **MineStar Truck Assignment**—schedules and assigns trucks, maximizes production and shovel utilization, minimizes truck wait time and manages shift changes.

**THE MINESTAR SOLUTION**

The total MineStar solution provides:

- Real-time monitoring of mobile equipment, material movement and equipment health
- Real-time control and optimization of the mining fleet
- Historical analysis and reporting of mine production
- Diagnostic and prognostic analysis of equipment health
- Enterprise application integration framework

MineStar Health automatically transmits VIMS data from the truck to a server instead of requiring it to be downloaded manually from the machine. MineStar...
Among leading mining companies, health and safety management is seen as an integral part of their operations. They’ve worked at the corporate level and at the mine site level to improve safety for operators, technicians and other personnel, with a goal of zero harm.

Recently they joined forces and united their voices to make health and safety a primary focus not only among miners, but among those who design and build the equipment they use to extract the critical resources needed to meet global demand.

“Mining companies face a common problem ensuring that earthmoving equipment is designed to be operated and maintained under all site conditions without causing harm to people,” says Jim Joy, director of the Minerals Industry Safety and Health Centre (MISHC) and professor of risk management at the Sustainable Minerals Institute at the University of Queensland, Australia.

Eight major mining companies—Anglo American, Barrick, BHP Billiton, FCX, Newmont, Rio Tinto, Vale and Xstrata—now participate in and provide resources for a unique partnership called the Earth Moving Equipment Safety Round Table (EMESRT). Officially formed in early 2006, EMESRT encourages manufacturers to improve Human Factors design of equipment in order to minimize health and safety risks. The group established a vision, purpose and scope, and developed design philosophies on certain risk areas. In late 2006 and again in late 2007, the combined representatives traveled throughout North America to actively engage with major surface mining Original Equipment Manufacturers (OEMs) on influencing equipment design.

Promoting a Health and Safety Focus

For decades, equipment users—specifically dealers and mine sites—have focused on human factors engineering and actively carried out modifications designed to mitigate health and safety risks. Rather than working to influence the base design process by explaining the fundamental problems they encountered, the industry instead focused on telling manufacturers the solutions to these problems.

What prompted the rapid implementation and progress of the EMESRT group? Tony Egan, a representative of Xstrata’s coal business, who was one of the pioneers behind EMESRT, attributes it to several factors.

“For one thing, the mining industry is changing with an ever-increasing focus on health and safety improvement,” he says. “Major global mining companies now have reasonably consistent health and safety expectations, but with local dealers providing current solutions there is difficulty in gaining a consistent application of these requirements globally. The solution involves a shift toward getting the design right at the factory and not leaving it to the local dealers.”

OEMs are equipped and resourced to provide the best solution, Egan explains. “With that common view among the earthmoving equipment users,
we’re actually in an environment that can get us around the table. The current eight member companies committed to EMESRT represent the large share of the industry and therefore have a greater collective influence.”

BUILDING EMESRT

While discussing different ways to improve safety more than three years ago, several global mining companies came up with the possibility of sharing their concerns and working to influence the design parameters of OEMs. Some OEMs had even encouraged such a movement so they could sort through the mixed “solution” messages coming from their individual customers.

The idea gained momentum and in March 2006, representatives of three major mining companies and MISHC met to discuss an alternative approach. Three more companies joined the group in 2006, and in October of that year the group agreed to terms of reference and adopted its official name.

MISHC was invited to coordinate the engagement process, with Joy serving as facilitator. Joy brings considerable Human Factors expertise to EMESRT. He was the leader of a research project funded by the Australian Coal Association Research Program (ACARP) titled “Improvement of Human Factors Engineering in Large Surface Mining Equipment Design.”

Human Factors Engineering is a science that focuses on how people interact with tasks, machines and the environment, recognizing that humans have limitations and capabilities.

ACARP provided additional funding for MISHC to assist EMESRT with the critical development phase of the OEM engagement process, which concluded in 2006. The 2007-2008 work plan was fully funded by member companies. In 2008, ACARP also agreed to provide funding for the dissemination of information about leading practice designs and issues—via a Web portal called MIRMgate (Minerals Industry Risk Management Gateway). (www.mirmgate.com.au)

The group set some aggressive goals:

- Develop and make available Design Philosophy (DP) information in selected topic areas.
- Understand how DPs align with or exceed expectations set out in standards and regulations, including the International Standards Organization (ISO).
- Develop and make available a Human Factors design process “journey” tool designed for OEM self assessment.
- Encourage OEMs to engage with member companies to participate in OEM operability and maintainability design reviews using a structured process.
- Use MIRMgate as a repository for DPs, lessons learned and leading practices.

IDENTIFYING THE GAP

Despite some excellent work in several areas, many of the Human Factors design issues for the mining equipment of 30 years ago remains today, says Alan Miskin, an EMESRT team member representing BHP Billiton. “Today’s large mining equipment is
relatively unchanged in the past 30 years,” he says. “The size of equipment has increased with advances in tire technology, engines, control systems and drive systems. But how else has the mining equipment changed to meet customer safety needs? If the end-users did not need these changes, they would not be modifying equipment themselves or forcing their dealers to do it.”

Despite the fact that earthmoving equipment is generally designed to recognized international standards, Human Factors design aspects sometimes fail to meet customer requirements with both company and regulatory standards, as well as controlling risks to As Low As Reasonably Practicable (ALARP).

“This has created a gap or ‘design vacuum’ between OEM designs and customer needs, which allows inadequate opportunity for identifying and managing residual risks that may exist,” says Joy. “While mining companies have not been happy with this design gap, EMESRT members agreed that what they had been doing to influence manufacturers wasn’t successful. Working independently and attempting to influence OEMs with design solutions hadn’t produced the desired results. Mining companies would oftentimes send conflicting messages to OEMs on how to resolve an issue.”

“We needed to get away from telling manufacturers what specific solutions we wanted added on to existing designs,” Miskin says.

“We changed direction to say: ‘Let us tell you the problem. You’re the ones with the engineering know-how to fix it.’ EMESRT is about trying to align the understanding of risk with the expectations of how we can mitigate them.”

Egan agrees. “A learned man once said, ‘A problem will never truly be solved at the level of thinking at which it was created.’ This is true of this issue,” he says. “We realized that as long as we splintered our voice—with each telling OEMs how to change existing products—rapid change in the base designs was difficult due to the commercial and resource constraints of manufacturers.”

**OUTLINING THE PRIORITIES**

EMESRT members agreed that their ability to align company requirements and expectations for Human Factors design would be critical for presenting a common voice to OEMs. They combined their individual expectations into the development of Design Philosophies that outline:

- Objectives
- General design outcomes
- Risks to be mitigated
- Leading practice examples of industry attempts to mitigate risks

EMESRT DESIGN PHILOSOPHIES

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<th>1. Equipment access &amp; egress</th>
<th>10. Guarding</th>
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<td>2. Working at heights</td>
<td>11. Displays, controls including labeling</td>
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<td>3. Noise</td>
<td>12. Tires &amp; rims</td>
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<td>14. Operator workstation</td>
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<td>6. Dust</td>
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<td>8. Visibility/collision detection &amp; avoidance</td>
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Eight of these philosophies—indicated in bold—were championed by focus leaders drawn from the EMESRT group and developed in 2006 and 2007. The remaining topics will be developed in 2008.
Each Design Philosophy sheet is supported by images that depict both the risks to be mitigated and the leading practice example solutions developed by mining companies and other third parties. The aim of a Design Philosophy is to provide information to help OEMs design equipment with risks mitigated using the ALARP principle.

The group identified 15 topics as priority areas for 2007 and 2008: Access and egress; working at heights; noise; vibration; fire; dust; isolation; visibility/collision detection; machine stability/slope indication; guarding; displays; controls, including labeling; tires and rims; manual materials handling; work postures; and confined space.

“These philosophies provide an image of many Human Factors problems,” says Joy. “They represent a significant step forward based on the common voice of the EMESRT members.”

Information is disseminated using the MIRMgate Web portal, as well as an EMESRT Alert Service that notifies MIRMgate users when new information related to any of the 15 design philosophies is released.

“We’re making it as easy as possible for OEMs to be aware and have access to resources,” Joy says.

RESPONDING TO EMESRT

As EMESRT continues to work on the rest of the design priorities, identify and research new issues and further its relationships with OEMs, the group has delivered enough information to give manufacturers some areas on which to focus. EMESRT would like to see OEMs:

• Incorporate the Design Philosophies into their equipment design process in the early stages
• Communicate and share knowledge
• In the conceptual phase, conduct design reviews using OMAT (Operability and Maintainability Assessment Technique) developed by EMESRT, or a similar task-based risk identification technique
• Accelerate development of safety improvements
• Partner in safety initiatives beyond equipment design

Incorporating the design philosophies

The Design Philosophies are meant to be used to influence earthmoving equipment in the design phase—the most strategic time to develop ways to mitigate risks. For Caterpillar, the key will be embedding those philosophies into the company’s own design guide.

“You’ve got to build this in from day one,” says Cameron Ferguson, product safety and engineering solutions manager in the Technology and Solutions Division. “Our designs already are equal to or above published international standards and some regulations. But we are and will continue to strive to do more than that.”

Caterpillar’s Dan Hellige, safety and sustainable development manager in the Global Mining Division, agrees. “We need to drive EMESRT’s input in a rigorous manner at the very beginning of the design process. We don’t want to look at post-production fixes; we want to consider their input in the early part of the New Product Introduction (NPI) cycle, in the strategy phase. Caterpillar and EMESRT are not that far apart. Our safety design guide brings years of experience and it’s not much different than EMESRT’s Design Philosophies. We need to look at how our priorities align.”

Bridging the knowledge gap

A lot of the progress EMESRT hopes to make is less about specific design improvements and more about communication and changing the way people look at things. “You must understand why you do things,” says Egan. “The goal is to get manufacturers to think about designing safety into all aspects of what they do. We must bridge the knowledge gap between users’ performance needs and manufacturers’ design engineers.”

“Get a design engineer and a user in the same room,” says Miskin of BHP Billiton. “Find a mechanism that transfers the knowledge among the engineer, the standards and regulations guy, and the user.”

“There might be good and reasonable reasons for things. And that’s fine,” Miskin continues. “In that case, think sideways. If standing on top of a machine to wash windows is dangerous, the only solution isn’t to make a safer place to stand to do the job. Can the source of the dirty window be eliminated? Can the window swing over? Can you put in a better wiper/washer system so the window doesn’t need to be manually washed at all?”

CATeRPIllAR AND EMESRT: WORKING TOGETHER

As part of their North American OEM meeting schedule, EMESRT representatives recently participated in a day-long forum at Caterpillar’s Edwards Demonstration and Learning Center, sharing their progress with Caterpillar product group leaders and other stakeholders, and listening to improvements and potential solutions under development at Caterpillar.

“There’s no doubt Caterpillar is committing resources to better equipment design and we commend them for that,” says Tony Egan from Xstrata Coal. “But that doesn’t mean we’re not going to challenge them to do more.”

Caterpillar’s Dan Hellige, safety and sustainable development manager in the Global Mining Division, welcomes the input. “Sometimes the challenge has been getting that input. We welcome it. You’re helping us keep pace.”

Hellige says he feels confident that EMESRT and Caterpillar can work together because they share common goals. “EMESRT knows that we are invested in this process and will do all we can to listen to concerns and keep those lines of communication open.”
Assessing the safety risks

As manufacturers requested during the 2006 meetings, EMESRT has developed a risk assessment tool—called the Operability and Maintainability Analysis Technique (OMAT)—to help OEMs learn all the potential risks before beginning the design of a piece of equipment.

OMAT is a qualitative risk assessment technique, which systematically assesses the risks to be mitigated. It is a four-step process that initiates the creation of a flow chart for all tasks and concludes with a comprehensive risk registry for a particular piece of equipment.

“Having OMAT or something similar stops the emotive arguments,” explains Egan. “Do we all understand all aspects of the issue? Then we can all agree on the outcome. It’s all about wider knowledge sharing between users and the designers.”

Egan illustrates the concept this way: Traditionally, prescriptive or rule-based industry legislation gave miners the rules to run their operations; however, this clearly did not prevent incidents from occurring. Contemporary risk-based legislation requires the development of risk management systems that require the systematic identification of all risks on a mine site, then a series of controls are established specifically for that mine. The higher the risk, the more robust the control required.

“Another way to look at it is speed limits on the road,” Egan continues. “These rule-based limits apply in fine weather, but should conditions change—like when it rains and you continue at the maximum limit—then an unacceptable level of risk may occur in the conditions. You need to assess this and adjust your driving to suit the varying conditions. In many cases local controls are too weak for the level of risk and ultimately require hard barriers through changing the original design.”

Accelerating the improvements

EMESRT is clear about its main purpose—to accelerate development and adoption of leading practice designs for earth moving equipment.

Caterpillar leaders don’t disagree with the need for speed. But they point out several issues that come up when the development process is accelerated.

“Why don’t we respond as quickly as our customers would like on some issues?” asks Kent Lynch, marketing professional in Caterpillar’s Track-Type Tractor division. “Because our engineers need to ensure that reliability and durability are deliverable in their designs. It’s cultural and emotional for our designers. They want to ensure that the design meets all potential customer requirements and exhibits reliability prior to release.” EMESRT leaders say they think mining companies would agree to take on innovative solutions that are in the advanced testing stage. “What if we had an expanded field follow testing program?” asks Craig Mamales of Rio Tinto. “If the OEM tells us that we’re taking it on a caveat basis, I think we would do that.”

Lynch agrees and notes that mines must accept a potential loss of availability that comes with adopting some of these enhancements. “Let’s work together to find an appropriate level of content and reliability to meet miners’ needs,” he says.

MAKING SAFETY A DIFFERENTIATOR

The obvious benefit of building equipment that mitigates the risks (to ALARP) described in EMESRT’s Design Philosophies is that operators and maintainers will be safer. But having safety improvements also can be a marketing differentiator for OEMs.

“It used to be if a mining machine was strong, reliable and built with quality, it could differentiate itself in the marketplace,” says Egan. “Now the health, safety and environmental attributes of the machines are increasingly important to users. An OEM can give value to these operability and maintainability aspects and further differentiate the machine in the marketplace.”

Egan concedes that it can be a challenge selling the value of above “standard” safety features to those who look at the bottom line without understanding the real risks. “Our aim is to use the Design Philosophies to engage and inform users and engineers alike.”

Craig Mamales of Rio Tinto offers this example: “A mine site ordered a Cat® D11T, which came with a Work Area Vision System camera system for improved visibility. The property opted not to take the camera because the purchasing department didn’t think it was necessary. A risk assessment
helped them understand the value of the camera—the operator couldn’t see the ripper—and the site then recognized the value of the system. The additional explanation helped get everyone—from the purchasing group to the operator—on board.”

Joy says the acceptance of safety features will be generational. “It’s like the auto industry,” he explains. “Ten years ago, you’d only find airbags on a Mercedes Benz. Today you can’t buy a new car without them. It took a change in the community. Now it’s cheaper for automakers to put airbags in every car than it is to offer them as an option.”

Craig Ross of Barrick Gold is confident that change will happen. “There has been a great deal of interest,” he says. “Next year will tell the tale. Our people who are buying equipment are now starting to ask the right questions. I haven’t seen any resistance.”

LOOKING TO THE FUTURE

The future of EMESRT appears strong. “Interest is high, feedback is positive, and we’re receiving in-kind support from many areas of the industry such as the International Council on Mining and Metals (ICMM),” says Egan. “2008 is about getting the word out and educating mine sites.”

Because all OEMs base their “standard” machine designs on published standards from around the world, EMESRT has begun the process of analyzing how the Design Philosophies align with or exceed expectations in standards and regulations, including the International Standards Organization (ISO), which represents the national standards institutes of 157 countries.

EMESRT has initiated an engagement process aimed at establishing an effective relationship between EMESRT and OEMs. The group also has agreed to work toward educating user mines about the design philosophy aims and to encourage use of the Design Philosophies in the purchasing process for new equipment.

EMESRT: VISION, PURPOSE AND SCOPE

VISION
An industry free of fatalities, injuries and occupational illnesses associated with operating and maintaining surface earth moving equipment

PURPOSE
Accelerate development and adoption of leading practice designs for earth moving equipment to minimize the risk to Health and Safety through a process of Original Equipment Manufacturers (OEM) and user engagement

SCOPE
We will:
• Focus on design of earth moving equipment operating on the surface at mines
• Provide aligned design expectations based on risk
• As member companies, provide resources and funding for EMESRT activities

We will not:
• Discuss commercial issues or anything of an antitrust nature
• Share OEM confidential information with other OEMs
• Provide approval for OEM or third party design
• Impose adoption of solutions on member company sites

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The shape and size of LKAB’s Malmberget mine make it ideally suitable for large-scale, sub-level caving, employing the remote operation of load-haul-dump machines. In addition to removing operators from potential danger zones, automation has increased productivity 10 to 20 percent. 

Disclaimer: The orange arrows on photos are drawn in for visual effects and do not actually exist.
Underground mining companies and equipment manufacturers have been cooperating at an unprecedented level to ensure the safety of underground workers. A considerable degree of this effort has been directed—with the aid of computers, sensors and video-links—toward the removal of workers from either a danger zone or the underground environment altogether.

Today, virtually every modern mining operation has been automated to some degree. While some have benefited only marginally, others have seen a dramatic change with regard to remote working due to the size, structure or character of the ore body.
TAILOR-MADE FOR AUTOMATION

Nowhere have these efforts been more visible than with the autonomous drilling and load-haul-dump (LHD) work at LKAB’s Malmberget operation. In many ways this ore body could have been tailor-made for extraction by sub-level caving and, therefore, mechanical automation.

The Malmberget mine, owned and operated by Luossavaara-Kiirunavaara Aktiebolag (LKAB), started production in 1888 and since then has produced over 350 million metric tonnes (386 million short tons) of iron ore.

Malmberget’s iron ore reserves, spread over an underground area approximately 5 by 2.5 kilometers (3 by 1.5 miles) have been estimated as 187 million metric tonnes (206 million short tons), with its measured, indicated and inferred resources accounting for a further 176 million metric tonnes (194 million short tons) with the ore bodies remaining open at depth. Furthermore, with its reserves grading at 43.6 percent Fe, Malmberget is among the world’s purest metal deposits. Its current annual extraction rate is over 12 million metric tonnes (13 million short tons). Located at Gallivare in northern Sweden, the mine contains approximately 20 ore bodies, of which 10 are currently being exploited. LKAB employs about 1,000 people at Malmberget; about 900 work in mining processing and administration.

MALMBERGET’S MINING METHODS

Large-scale sub-level caving is the method of mining. Production drilling (at the access level) is undertaken by five electric-powered automated rigs, with each rig drilling approximately 10,000 meters (33,000 feet) of 11.5-centimeter (4.5-inch) diameter holes per month. Each hole averages 50 meters (165 feet) in length and, while the direction and number of holes varies depending on the structure and orientation of the ore at that location, most “production fans” contain 10 holes resulting in 10,000 metric tonnes (11,000 short tons) of ore being blasted per 3.0- to 3.5-meter (10- to 11.5-foot) slice. The emulsion explosives are pumped down-hole by two trucks for production charging and four trucks for drift development. All drifts are supported by roof bolts and shotcreting.

The blasted rock, now funnelled by the unfractured host rock, percolates down toward a series of pre-prepared production draw points, from where it is loaded by 20- to 25-metric-tonne (22- to 27-short-ton) capacity LHDs. The LHDs, which include Caterpillar® R2900s, work from the production sub-levels. The ore is trammed at a daily rate of approximately 50,000 metric tonnes (55,000 short tons) to the haulage level, from where it is transported in 120-metric-tonne (132-short-ton) capacity trucks to the underground crusher stations. After crushing, the ore is skip-hoisted to the surface for magnetic-separation processing and onward shipping.

It is the very nature of the ore body (i.e., massive and slightly inclined) and, therefore the mining operation (i.e., sub-level caving) at Malmberget that lends itself to the automation of both the drilling and LHD work. “We are employing sub-level caving because it is the most productive mining method for this ore body,” says Bjorn Koorem, Malmberget’s mine manager. “But perhaps our biggest surprise is that during recently completed LHD trials, automation has been shown to increase productivity by between 10 and 20 percent.”
**AUTOMATION EVOLUTION**

The original remote working of LHDs, termed line-of-sight remote, involved an operator employing a chest-mounted console from which to control the LHD while its bucket was loaded and then backed away from the ore pile. Once this task had been completed, and the machine had been moved away from the danger zone, the operator returned to the cab and manually drove the machine to the dump point. Once emptied, the operator drove the machine back to the loading location.

While remote working met many of the criteria for removing the operator from the most dangerous area of operation, accidents continued to occur when safety procedures were not observed. Therefore, mining companies concurred that the goal was to remove human exposure to injury. This bold decision was the initiative that eventually led to the development of the MINEGEM™ system.

Caterpillar formed a joint venture with Lateral Dynamics to develop the MINEGEM Automation system as an attachment to standard LHDs. The system offers two levels of control: co-pilot, with operator-assisted automatic steering, and auto-pilot, under which the loader can automatically tram, dump and return to the load point.

The initial refinement of the remote system to the co-pilot mode removes the physical need for the operator to steer the machine. The operator, based at a console in a control room (often at the surface), monitors the machine’s location on a mine plan while using a joystick to instruct the machine in which direction to travel. On-board scanners and a radio network mounted along the journey route ensure the machine self-drives along a safe path.

**MALMBERGET TRIAL**

The Malmbärget mine was chosen as one of the locations for MINEGEM development, recently completing a successful 12-month trial using the Cat® R2900G XTRA LHD.

“We knew that there were going to be two significant advantages to be achieved by employing the MINEGEM system,” explains Ola Soderholm, technical specialist at Cat dealer Pon Equipment AB. “Firstly, removal of the operator from a potentially dangerous environment, and secondly, the ergonomic advantages to an operator being able to work from a chair in a control room rather than from an uncomfortable seat underground. The purpose of the trial was to show that the practice matched the theory.

What we hadn’t quite appreciated was the extra advantages we would be uncovering: an increase in utilization and productivity, and less machine damage. I think we will find that with time, other advantages will emerge.”

Based on the trial results, a 12-plus month “production-result” based rental agreement was set up between Caterpillar and LKAB. The next generation of the MINEGEM system is due to be launched in 2009 as the Mk3.0 model with newly developed software. LKAB is currently progressing plans to increase its annual production to 20 million metric tonnes (22 million short tons) of crude ore and 9 million metric tonnes (10 million short tons) of pellets. It is anticipated that a significant part of this production increase will be achieved through the implementation of the MINEGEM system.

**AUTO PILOT AND BEYOND**

The MINEGEM auto-pilot mode allows the operator to select a goal for the machine and send it there using its own self-guidance system. A normal routine for the MINEGEM operator is to fill the bucket in remote mode, then set the mode to auto-pilot with the ore pass as the goal. The machine will then tram to the dump point, empty the bucket and return to the draw point automatically using its own self-guidance system, without any input from the operator.

While a manually operated LHD may achieve greater tramming speeds than one fitted with the MINEGEM system, it cannot do so without the risk of striking the sidewalls. Additionally, production over a 24-hour period may be improved with an automated LHD.

Operating under auto-pilot, several machines can be operated by a single operator. Available options...
include traffic management, production statistics capture, and data sharing.

The actual hardware setup (i.e., line-of-sight aerials, a radio and repeater network, security gateways and a leaky-feeder cable) is easily achieved. In fact, at the Malmberget mine, LKAB technicians took only a few days to successfully complete the setup for the second MINEGEM production trial area. In addition, all the equipment can be moved and re-used in another location if necessary.

SCANNERS AND LADARS

In the late 1990s, when faster and more powerful computers were combined with other developments in the field of scanning technologies, MINEGEM LHD automation became a true solution for underground mining operations.

“Scanning provided the definitive ‘Eureka!’ factor as far as autonomous hauling was concerned,” explains Stuart Burridge, a product specialist.
with Caterpillar Underground Mining. “Now we can visually scan and recognize the sidewalls and their profilers.” To do this, the system employs the LADAR (laser-radar range sensing) system, which provides spatial information to the machine by comparing these profiles to an existing database provided from the mine map. The system is then programmed to make a decision that it transmits to the machine as a command: left, right, forward, backward, steady speed, accelerate or break.

“It has been these two interrelated developments—high-speed computers and scanning technology—that have enabled underground automation to become a reality, and subsequently a commercial success,” says Burridge.
“In addition to constant machine status and engine monitoring, the operator also receives audio feedback from the machine. Machine health status is also displayed on the remote operator’s console.”

**ADVANTAGES OF MINEGEM**

Originally designed to be employed in dangerous areas, the MINEGEM system has since proved to have additional advantages: speed-efficiency, a reduction in damage to the LHDs, and virtually continuous equipment utilization, uninterrupted by shift changes and the need to evacuate the area for ventilation after blasting. It is estimated that the overall shift speed-efficiency increases productivity by approximately 25 percent, while side-wall collisions resulting in LHD damage and the need to repair both the equipment and the collision zone are reduced to zero. Additionally, the ability to tram regardless of shift patterns or blasting schedules has been estimated to increase the daily production period by between four and six hours.

The MINEGEM system already has been employed at several world-class operations, including Rio Tinto’s Northparkes Mine, where the system attained more than 95 percent availability, while operating an average of 10 hours per 12-hour shift.

“As one would expect, some LHD operators are strongly opposed to any change, while others see this as a positive step forward, which will remove them from a dangerous, hot, dusty and humid environment,” says Soderholm. “It was a little easier for some of the younger men, who have more computer experience, to get used to the console and joystick workings. To them it is a little like running a video game.”

Soderholm explains that computer skills are not nearly as important as knowledge of the way an LHD operates. “Experienced LHD operators do not necessarily have the computer skills, but they do have a better understanding of what is happening to the machine, what it is being asked to do, and more importantly what can go wrong and the indicators that all is not right,” he says.

“In my opinion, traditional understanding of the way the machine works, how to make it perform to its best advantages and the very special conditions in underground mining operations, far outweigh any computer skill argument.”

**MOVING FORWARD**

While computers and scanners are often considered the two tools that provided the step-change necessary for the automation of LHDs, Burridge has predicted that the next significant step will follow the development and commercial availability of the self-learning computer.

“Once this has been achieved, the auto-dig program will become more capable, which will be the final phase toward achieving the fully automated loader,” he says.

“Following this it will be possible for 12 to 15 machines to work simultaneously servicing a block caving area with associate fleet management and traffic control systems to allow them to safely work side-by-side.”

While some mines will always require people to work underground, the MINEGEM system is making it possible for some hazardous, repetitive and fatiguing tasks associated with the operation of LHDs to be done from the comfort and safety of a remote control room. The fact that this method of controlling and supervising an LHD has been shown to be efficient, effective and more productive, simply adds to its value.
The very shape and massive size of its ore deposit has led to Malmberget becoming a classic example of the sub-level caving mining method. However, more recently the mine was selected as a testing ground for a new generation of underground loader automation systems being pioneered by Caterpillar as part of the industry’s loosely-termed “rock factory” concept.

“The rock factory concept involves taking the large open-pit mines of the world today and turning them into the successful underground operation of tomorrow,” explains Stuart Burridge, a product specialist with Caterpillar Underground Mining. “Over 80 percent of the world’s known ore-bodies today were discovered by examining surface outcrops. Once you get to the bottom of the open-cut—usually dictated by the prohibitive cost of hauling the ore from the bottom of the pit to the surface and the extra amount of overburden removal required to expose a smaller and smaller quantity of ore—there is still ore to be extracted by switching to an underground operation.”

The rock factory concept began as a grass-roots re-evaluation of mining and its traditional extraction methods. This initiative intended to pursue the notion that underground deposits could produce the same tonnages that previously had been possible only from open pit operations. To realize this vision it has been necessary to harness the power and versatility of computerization and its associated technology. Although only in its infancy, the rock factory concept has already achieved some tremendous results.
The primary deliverable for any mine maintenance organization is available hours that the operations department can use to meet its production goals. Performance in this area is reported in terms of availability. Virtually every mine measures and tracks some form of availability. It’s a key measurement by which mine management quantifies the performance of its equipment fleet, and it provides the basis for identifying equipment needs.

Three critical factors affect equipment availability: The design of the product, the application/operation in which it is used, and the maintenance it receives during its time in service. Of those three, maintenance offers the greatest opportunity for improvement.

“Maintenance is the factor that offers mining companies the best opportunity to influence and control the performance and availability of their equipment,” say Abelardo Flores and Jim McCaherty, co-authors of “Performance Metrics for Mobile Mining Equipment,” a Caterpillar guideline created to assist mining equipment users in the definition and use of uniform criteria for the evaluation of product and project performance. “The end-user has enormous ability to influence performance through maintenance practices.”

Successful sites use key measurements to improve availability

THE IMPORTANCE OF MAINTENANCE

Maintenance and repair process implementation and resource selection—including facilities, tooling, support equipment, lubricants, and contamination control practices—all have a direct bearing on the final results owners receive from the equipment they purchase.

The most successful mining equipment management operations realize that maintenance goes well beyond draining oil, changing filters and performing the basic routines recommended by the manufacturer.

“In addition to preventive maintenance, successful mines also incorporate predictive and corrective procedures in order to be fully effective,” says Flores. “The term ‘equipment management’ implies a cohesive effort on the part of the entire organization—not just those routine activities performed by the maintenance department.”

Beyond having predictive, cohesive maintenance practices, the focus of the Caterpillar® document...
is on one key factor: Measurement. “It's true that the availability of your equipment depends on the performance of proper maintenance and repair,” explains Patrick Mohrman, Caterpillar Global Mining site support manager. “In order to understand if the maintenance and repair are being performed correctly, you need to measure. We at Caterpillar want mine sites to know how important this is. If you're not already measuring, you should be thinking about measuring.”

Machine maintenance is not an option. “In order to keep equipment working at peak performance, it must be taken out of service for maintenance and repairs,” Mohrman says. “However, when equipment is down for service or repairs, it’s not productive, so it’s not generating revenue. The successful equipment manager needs to manage this downtime effectively and efficiently in order to optimize the time the equipment is productive. The ultimate goal is to improve availability.”

**MEASUREMENT IS A MUST**

In order to quantify equipment performance, performance criteria must be put in place. The following hold true for most activities, including the management of mining equipment:

- You cannot manage what you cannot control.
- You cannot control what you cannot measure.
- You cannot (or at least should not) measure without a target.
- Without a target, you cannot improve.

“Management without metrics is, in reality, management by intuition,” says McCaherty.

Caterpillar recommends benchmarking—a process to identify best practices—to gauge performance relative to the competition or to monitor progress toward a specific set of objectives. The benchmarking process aids in the identification of weak areas, poor practices and opportunities for improvement. It’s a systematic, ongoing, continuous improvement process that requires a long-term commitment.

The results that come out of the benchmarking process may be called standards, measurements, metrics or Key Performance Indicators (KPIs). They quantify best practices for an operation and could be:

- Operational (payload management, delays in load times, truck exchange times, production, cost per ton, etc.)
- Application-related (grade/grade variation, rolling resistance, haul road maintenance, traffic flow, etc.)
- Maintenance-related (availability, utilization, etc.)

The benchmarks that Caterpillar has established for equipment management were designed to answer these questions:

1. How are we? Where do we stand today?
2. How much effort have we invested in getting where we are?
3. Is our situation the result of planned work?
4. What are the locations and frequency of our “pain”?
5. Is our situation stable? Is it sustainable?
6. Are we using “failures” as an information source?
7. Can we forecast the future?

“No matter how good a piece of equipment is, how good the maintenance is, or how easy the application is, sooner or later there will be problems,” says McCaherty. “What distinguishes the successful site from the less successful one is the organization that is in place, and how it deals with problems when they arise. Rather than ask, ‘How long will it be down?’ the knowledgeable equipment manager asks, ‘Why did it go down and what can we do to prevent this from happening again?’”

Unscheduled shutdowns (downtime) are the enemy of equipment management. Unscheduled shutdowns may be due to an equipment failure that can be solved with a technical solution; however, they may also be the result of a failure of the equipment management organization, whose responsibility it is to avoid equipment problems and failures. Either situation can be improved through the use of performance metrics.

**MEANINGFUL METRICS**

Although their calculation methods may vary, the majority of mines measure and report availability. While useful for providing a historical view of the past and present health of an equipment fleet, traditional availability measurements fail to give
the user a clear insight into why things are the way they are, what needs to be done to ensure a healthy situation remains healthy, or how a problem situation can be resolved.

Mines also frequently monitor and report a number of other parameters that provide information—but little else that could be viewed as either predictive (allowing the mine to be proactive) or corrective (enhancing the mine’s ability to develop action plans).

“Mines typically collect mountains of data and compile reports,” says Flores. “But oftentimes they don’t take advantage of that data to improve the operation—turning the data into information for use as ‘management tools’ to determine why a condition exists, what can be done to reverse a bad trend, or how to sustain a good situation.”

What do mining companies really want and need? “Reports that identify equipment problems—both current and future—document equipment health, and eliminate surprises,” answers McCaherty. “Reports should also help set priorities for problem management and continuous improvement activities that help mine sites focus their efforts and resources on the most significant issues affecting performance.”

Reports should be informational and also possess analytical, interpretive, predictive and corrective characteristics—stimulating thought instead of simply reporting results, says Flores. They also should be:

- Regular—typically monthly
- Timely—so management isn’t using old information
- Visual—so they are easy to understand at a glance
- Concise—because bigger is not always better
- Action-oriented—driven by functional objectives
- Easily understood—to encourage application and maintenance

“One very good rule of thumb is ‘Don’t generate more questions than you can answer,’” says McCaherty. “If you think of reporting as ‘applying what you know to what you want to know,’ the task becomes much simpler.”

A COCKPIT VIEW

Caterpillar’s experts developed a collection of “top tier” performance metrics called Key Performance Indicators (KPIs) that give mine managers a “cockpit view” of what they need to assess their situation.

“In the same sense that an airline pilot needs only a handful of the hundred or so sources of information he has at his disposal to safely land a plane, these KPIs are a small fraction of the performance metrics available,” says Flores. “Of course, there must be sufficient secondary information to permit the mine manager to proactively take necessary action if a problem is detected.”

Caterpillar has invested a great deal of time, energy and resources in developing these key metrics. “First we worked to determine the data available at most sites that could be developed into information and metrics that represent and correlate to fleet performance. At that point we were able to interpret what these metrics mean relative to site performance and to understand how they interact with each other. Finally, we devised a presentation format that enables the equipment manager to quickly and easily recognize critical issues,” says McCaherty. “We’re
very comfortable with using these KPIs to quantify and trend equipment health.”

The top tier metrics identified as KPIs are:

• Mean Time Between Shutdowns. Mean Time Between Shutdowns (MTBS) quantifies the average frequency of machine stoppages. It combines the effects of inherent machine reliability and the effectiveness of the equipment management organization in its ability to influence that reliability through problem avoidance. MTBS is the single most important measure of equipment maintenance management performance.

• Mean Time to Repair. Mean Time to Repair (MTTR) quantifies the average duration of machine stoppages (repair turnaround time), i.e., how quickly or slowly a machine is returned to service once a downtime incident occurs. MTTR combines the effects of machine maintainability/serviceability and the efficiency of the equipment management organization in delivering rapid remedial action in the execution of needed repairs.

• Availability Index. The ratio of MTBS (average shutdown frequency) to the sum of MTBS and MTTR (average shutdown duration), expressed as a percentage, is defined as the Availability Index. Unlike most traditional availability measures, the Availability Index allows the equipment manager to break down availability into its elements, i.e., frequency and duration of downtime events, and take appropriate remedial action.

• Percent Scheduled Downtime. The percentage of total downtime hours performed in a given period that have been planned and scheduled. By monitoring the percentage of downtime that has been planned and subsequently scheduled, the organization can assess its effectiveness and efficiency in defect detection and repair planning, scheduling and execution. A high percentage of scheduled downtime is indicative of a proactive organization.

• Maintenance Ratio. The dimensionless ratio of maintenance and repair man-hours to machine operating hours. It indicates the amount of effort required to keep equipment in service as well as the efficiency with which labor is deployed and the effectiveness of the workforce.

• Asset Utilization. The proportion of time that a machine is operating (operating hours) divided by the total calendar time in the period, expressed as a percentage. Asset Utilization can be used in conjunction with Maintenance Ratio to forecast manpower and resource requirements. Many mines schedule their equipment for use 24 hours a day, seven days a week. Maintenance must work with Operations to find windows of opportunity for maintenance and repairs.

• Top Problems. The distribution of problems affecting a fleet of equipment ranked in terms of MTBS, MTTR, impact on Availability and Costs. All mining companies have limited resources; the most successful operations use a Pareto analysis to identify top problems to obtain a clear understanding of the key issues they face, and establish priorities in order to focus their efforts and allocate resources.

**Basic terms**

**Performance Metric.** A term used to describe the outcome of any process used to collect, analyze, interpret and present quantitative data. It enables performance against a pre-defined target or benchmark to be monitored.

**Key Performance Indicator (KPI).** A top-level performance metric. KPIs may vary from site to site, by product, application or perspective. All KPIs are performance metrics—but performance metrics are not always KPIs.

**Target.** A desired goal; a standard by which a performance metric can be measured or judged. May vary by product, application or specific site.

**Benchmark.** A world-class performance standard relative to a specific performance metric; represents and quantifies best practice of an operation or of specific functions within that operation according to a specific performance metric.

**Shutdown/stoppage.** A event that takes a machine out of service. May be scheduled or unscheduled and includes all types of maintenance and repair activities except daily lubes, refueling and inspections executed during lube or refueling activities.
POWER
—A DRIVING FORCE AT DRUMMOND’S MINA PŘÍBBENOW
Mining companies have experienced tremendous growth in recent years as they expand to meet the global demand for materials. That rapid growth can lead to some significant obstacles—like the need to provide the clean, reliable power necessary to support the massive requirements of mining operations.

Such was the situation facing leading coal producer Drummond Ltd. (DLTD) at its Mina Pribbenow open-pit coal mine, located in the Cesar Coal Basin near La Loma, Colombia. The mine’s challenges included access to power, the allocation of power between the mine and its support facilities, large and regular fluctuations in load, regenerative power, generator set availability and fuel quality. Drummond turned to Caterpillar for guidance and technical support to overcome these barriers.

THE DRUMMOND OPERATION

The DLTD Colombian operation includes Mina Pribbenow; Puerto Drummond, an ocean port on the Caribbean Sea near Santa Marta; as well as coal transportation and handling facilities. DLTD transports the coal from the mine 193 kilometers (120 miles) by railcar on the renovated portion of the Colombian National Railroad System to Puerto Drummond on the northern coast for export.

La Loma coal meets worldwide sulfur regulations, and is one of the lowest sulfur and ash coals currently exported from Colombia. As emissions regulations are becoming increasingly stringent in many parts of the world, this coal, producing comparatively low levels of NOx, is desirable to utilities that are required to meet new emissions standards.

Investing heavily into production infrastructure in the last few years, DLTD has experienced significant growth at Mina Pribbenow. Shipments of Colombian coal from Mina Pribbenow have increased from 9.1 million tonnes (10 million short tons) in 2000 to 23 million tonnes (25.3 million short tons) in 2007, a growth of 253 percent, with 26 million tonnes (28.6 million short tons) expected for 2008.

Current Reserves at the Mina Pribbenow Complex stand at 561.2 million tonnes (618.6 million short tons). With El Descanso reserves of 1,763 million tonnes (1,943 million short tons) and total DLTD reserves in Colombia exceeding 2,333 million tonnes (2,572 million short tons), DLTD expects to reach 40 million metric tons of annual production within the next five years and anticipates a bright future. The innovative use of a conveyance system and apron feeders to move coal and overburden at the Colombian mine has enabled this growth.

Access to commercial electric power was not available when DLTD began this operation—and still is not available in the Cesar Coal Basin; therefore, DLTD has been responsible for generating all of its own power. A total of 21 diesel-fueled generator sets, including both Caterpillar® 3516 and 3516B models, are installed at Mina Pribbenow to provide prime and standby power.

Stan Grise, assistant superintendent of diesel power plants and maintenance department product support for DLTD, explains how the corporate and electrical engineering departments compared the options. “They looked at several different alternatives including smaller turbines as well as large diesel and natural gas engines,” he says. “Every analysis brought us back to the 2,628-horsepower engine of the Cat® 3516 and 2 MW Generator. We couldn’t find anything that would get us even close to the sheer rotating mass and kW/hp ratio they would generate. Even though the generator sets are designed to carry a constant load, they have performed unbelievably well with the cyclic loads of the Marion 8750 dragline.”

The reciprocating mass of this engine and generator combination are important when dealing with the regenerative power from a dragline. Even with the resistive load bank used to dissipate the regenerative power from the dragline, some of the negative kW is still absorbed by the generator.
and engine. In a complete dig cycle under extreme digging conditions, the dragline has logged peaks of 90° Boost 135 GPH & 2 MW Output and then back to 0 Boost, 0 GPH, and 0 kW on these Gen Sets (27 MW peak demand).

**DIVISION OF POWER**

La Loma has two main power sites, with 15 generator sets housed at a new power facility located adjacent to the new gas turbine plant and two kept at the former facility for back-up emergency power for the coal load-out facility—where coal is separated and prepared to meet the different quality needs of DLTD customers. Two Cat XQ2000 trailer-mounted power modulars provide back-up emergency power for the camp and as the motivator on one of the KRUPP Conveyor System Spreaders. An additional five 3516B Gen Sets will be installed for the start-up at El Descanso until a 110,000 volts High Line is completed.

As mine power requirements grew, so did the diesel generator plant. The original plant started operation in July 1998 with two gen sets, with an additional 16 units added between 1999 and 2000. As of March 2008, the Cat 3516 generator sets have generated 493 million kWh @ 12.18 kWh/Gal average LTD. Between 1998 and August 2004, the 3516 gen sets were the sole source of electric power for Mina Pribbenow operations, generating a record high of 86 million kWh and 117,000 operated hours in 2003.

In August 2004, DLTD brought online Phase 1 of a 58 MW capacity duel fuel (compressed natural gas and diesel) gas turbine plant. This addition was necessary to provide power required for 21 apron feeders and the first of three in-pit conveyor systems that went into production in 2006 and 2007. In October 2006, the company completed Phase 2 by installing an additional two LM6000 turbine units. This addition gives DLTD a total installed capacity of 196 MW. To date, the power plant has recorded 98 MW demand with all systems operating along with the apron feeders, electric shovels, dragline and dewatering pumps.

In January 2005, DLTD initiated the relocation of 15 gen sets to the new facility adjacent to the new gas turbine plant. The construction of the new diesel plant was necessary with the installation of the turbine plant and 110,000 volts substation and high line encompassing the entire Pribbenow Mine Complex. The diesel gen sets are 4160 volt boosted to 22,900 volts, then up to 110,000 volts and combined with the turbine plant power at a substation.

“Turbines will not operate under cyclic loads or absorb regenerative power, like those produced by the dragline,” explains Grise. “To be able to continue operating the dragline, the gen sets must be online and provide the power required for the cyclic and regenerative conditions of the dragline.”

One of the most important mining methods used at Mina Pribbenow is now powered 60 percent by Cat generator sets: the Marion 8750 Dragline with an 87.9 bank-cubic-meter (115-cubic-yard) capacity bucket. Requiring a considerable amount of the power generated at the site and representing the largest piece of mining equipment in Colombia, the dragline utilizes up to eight Cat 3516B generator sets, each rated at 1.825 kW (prime) and 2,000 kW (standby). In January 2008, the dragline began stripping river alluvium by direct loading apron feeders, averaging 59,000 bank cubic meters (77,000 cubic yards) per day of production. The process has been so successful, the company is currently disassembling a BE 2570 Dragline with an 87.9 bank-cubic-meter (115-cubic-yard) bucket located in Alabama to use at the El Descanso Mine in Colombia. With the addition of the second dragline, the demand from the Cat gen sets will again increase.

“The dragline is critical to the mining operation,” says Sergio Maury Benedetti, onsite project manager with General de Equipos de Colombia, S.A. (GECOLSA)—La Loma, Colombia’s Cat dealer. “It is very important to maintain a steady, stable source of power to keep it working.”

**REGENERATION AND HARMONICS**

Regenerative power is another challenge presented—and overcome—at the Mina Pribbenow power station on a routine basis. “The electrical load on the power station varies greatly, and often abruptly,” explains Joe Rad, Caterpillar Global Mining commercial manager for Latin America. “This is due largely in part to the operating profile of the dragline.”
“As the dragline digs, swings and dumps throughout its work cycle, the 3516B-driven power station needs to quickly respond by delivering the electric power required by each cycle, routinely in block-load fashion,” Rad continues. “Design and application considerations were given to the 3516B generator sets and power station controls to ensure optimal power quality is delivered to the dragline, mine site and campsite.”

As outlined in a white paper by Drummond’s Larry Casson at a meeting of the Western Mining Electrical Association, electronic controls play a major role in the operation of the dragline. “The Marion 8750 dragline is capable of regenerating up to 60 percent of peak motoring power. To account for this, a six-stage resistive load bank was installed to absorb regenerative power not being utilized by other mine equipment. The diesel generators can absorb a small amount of regenerative power, but the load bank is required to absorb larger amounts of regenerative power,” wrote Casson.

“Generator control is accomplished by using a combination of load share modules and programmable logic controllers (PLCs),” Casson added. The load share modules control load share (kW), and voltage control (kVAR/PF) between generators as well as provide synchronizing control when bringing on additional generators.

The schedule for bringing generator sets online is programmed in advance, but the central PLC in the control room is monitored carefully and variances are made if needed. “We can isolate depending on the load and modify based on increases or decreases in power requirements,” says Maury.

The installation of electronic controls has saved the mine a significant amount of diesel fuel. “In the past, the engines would run whether they were loaded or not, but now if there isn’t any power consumption in over 10 minutes, it starts shutting the generator sets down,” explains Grise. “In addition, there is a radio signal from the dragline to the power plant that tells us when the generator sets need to be shut down or started up. Lowering our fuel consumption has resulted in significant savings for us.”

Grise and Casson discussed the monitoring, testing and different modes of operation, and agreed they wanted the new facility to be able to monitor all engine and generator parameters from the control room as well as use the Caterpillar Customer Communication system and Allan Bradley RS Logix 500 to monitor all PLC and System functions. The plant also has the capability to load bank test any of the gen sets on site; can base-load as many generators at any kW to supplement the turbines without affecting the gen sets that are operating the dragline, or operate the entire mine in the event the turbine plant is shut down for some reason.

MAINTAINING FOR MAXIMUM AVAILABILITY

In addition to the project manager, one electrical technician and two mechanical technicians from GECOLSA maintain the machinery for maximum performance and efficiency. Important information from the generator sets is sent to the PLC to alert the team when maintenance is required beyond the regular schedule. For example, these reports will indicate when various filters need changing and if anything is out of adjustment in the engine or generator. “Because the loads on generator sets are always changing it is important to rely on the reports generated,” says Maury.

A laptop computer with Caterpillar Electronic Technician software is connected to the generator sets at least twice a day to download data that is reviewed. “We check parameters like fuel consumption, fuel and air restriction, fault alarms, fuel and hourmeter readings—which are exported into a program that tells me how many hours the engine ran in a shift and how many gallons it consumed per hour,” says Grise. “If consumption increases, we know we need to do more testing and make adjustments.”
“All of the generator set maintenance between overhauls is handled onsite,” Grise explains. When the engine requires an overhaul, the engine is sent to GECOLSA’s Cat-certified Component Rebuild Center in Barranquilla, Colombia. “We do all of the scheduled maintenance and testing and adjustments to the engines and generators per Caterpillar guidelines, and it’s made a big difference.”

Grise says the company has experienced excellent results over the years. “We now average about 4,500 operating hours per month on the 19 generator sets engaged in prime power. In previous years we have operated as high as 9,700 hours per month,” he says. Caterpillar calculates when an engine should be ready for replacement based on the number of gallons of fuel consumed by an engine. For this site, that number was set at 2.8 million liters (750,000 gallons), and they are still going strong at almost 3.4 million liters (900,000 gallons), surpassing 26,000 operated hours.

**FUEL FILTRATION**

Quality of fuel plays a major role in the availability of power. The fuel may come from refineries in Colombia or be imported from international refineries. “We found that the fuel quality was never the same from one tanker to the next,” says Grise. Several factors can affect diesel quality, which if not addressed, can be a detriment to the engines. “With average temperatures of 38 degrees C (100 degrees F) and very high humidity, condensation is always an issue. With the amount of equipment we currently operate, our monthly fuel consumption averages 5 million gallons; you better have a good fuel filtration system,” Grise says.

DLTD has procedures in place to ensure the quality of fuel received, and also has developed a bulk fuel filtration system. First, fuel is filtered when it is offloaded from the tankers into two 1.8-million-liter (476,000-gallon) or three 420,000-liter (111,000-gallon) fuel storage tanks. “At our high-flow filter stations we can unload the fuel at approximately 2,270 liters (600 gallons) per minute,” says Grise. As the fuel is off-loaded from the tankers, it is filtered at 25-micron micronic and 25-micron coalescer. Second, the filtering systems...
at both storage facilities are set up with a second set of high flow filters that are used periodically to polish the fuel. This is accomplished by continuously pumping the fuel in the tanks through the filters back into the tank for several hours. The time required to accomplish a thorough polishing depends on the amount of fuel in the tank (from four to 24 hours). Finally, fuel is filtered as it is dispensed from the storage tanks.

Fuel from the storage facilities is dispensed in several different ways. Tanker trucks are used to transport fuel to satellite fuel stations located around the mine for the overburden truck fleet. Fuel trucks are filled to service the track equipment in the pit. Underground fuel lines are used to dispense fuel to the coal loadout facility to fill the coal haul trucks, dozer and RTD fleet. Each of these fuel stations utilizes 5-micron micronic and 5-micron coalescer filter elements in their vessels prior to dispatching as well. DLTD uses only high quality fuel filters in all of the fuel storage and pumping stations.

A dedicated group of DLTD employees take care of all of the fuel tanks including draining the water every morning from all the fuel storage tanks and filter vessels, replacing the filter elements, maintaining the pressure differential gauges and fuel pumps, and periodically calibrating the fuel meters.

“Now that we have this advanced filtering system, we can maintain a substantial reserve on the mine site,” says Grise. “Even when the refinery is down or barriers to transportation arise, our work continues because we have a steady source of fuel for all of our equipment—including the generator sets.”

LOOKING AHEAD

The relationship between Caterpillar and Drummond Company began more than 73 years ago in the United States, when Caterpillar dealer Thompson Tractor Company provided a new coal mining customer, H.E. Drummond, with machines, replacement parts and service to start up his open-pit operations in Alabama. “When operations shifted to a greenfield open-pit mine in Colombia, it was natural that Drummond wanted to involve Caterpillar with their operation from day one,” says Keith Malison, Cat Global Mining marketing manager in Latin America. A partnership between Thompson Tractor and GECOLSA quickly developed to meet all of Drummond’s needs. Sales, service and support are now handled solely in Colombia.

Grise is proud of the quality of his onsite technicians. “I’ve got some excellent men,” he says. “I’d put them up against any power generation mechanic or electrician anywhere. In previous years when there were as many as 16 of 18 units on line 24/7, these men did several complete stripped-to-the-bare-block overhauls here at the power plant as fast as the CRC could do them with excellent results.”

Drummond has made a number of modifications to the Cat gen sets to fit its application as well as increase the life of the engine and generator. “We sit down with the electricians and mechanics from GECOLSA, explain what we want the generator sets to do, they draw it out, and together we make it happen,” Grise says. “Most of these guys have worked for me for the last seven years and they’re like family to me.”

More than 95 percent of the mobile equipment and engines used at the mine and port facilities bear the Caterpillar name. “In fact, one of the largest populations of 850-hp Cat D11R tractors and 240-ton Cat 793D trucks are at work in Mina Pribbenow and Drummond’s expansion project,” Malison says. Grise says the company has 76 Cat D11Rs—more than any company in the world. By the end of 2008, the company will have 145 793B, 793C and 793D Cat trucks.
Caterpillar recognizes that running a safe and environmentally responsible business is a top priority for mining companies. To support these efforts, the company will bring together industry leaders and external experts to share best-in-class practices in sustainable development during a Caterpillar-sponsored Health, Safety, Environment and Community forum on Sept. 19, 2008, in conjunction with MINExpo 2008 in Las Vegas, Nev., USA.

The format of the day-long event is an open-house setting with three learning venues:

- **Gallery Walk**, an area where mine companies and other industry organizations will exhibit HSEC best practices.
- **Discussion Arenas**, where recruited experts will debate issues and engage in give-and-take discussions with an audience of peers. There will be moderated sessions on relevant topics, including:
  - Guidelines Development—SD evaluation of mining projects in the context of local, regional and national scales
  - Material Stewardship—Rate of Extraction and the Product Life Cycle
  - Safety—Obtaining Vision Zero
  - Biodiversity and Footprint Management
  - The Reality of Climate Change
  - Managing Operator Fatigue
  - Work Force Management: Skills Shortage and Development
  - Sustainable Indigenous Economic Development
- **Gathering Grounds**, an open venue with refreshments, to relax and connect with other sustainable development professionals for one-on-one discussions.

For information on how to participate, please contact your local Cat dealer.

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**DVD PROVIDES PRACTICAL SOLUTIONS TO MINING LIFESTYLE CHALLENGES**

As previewed in the last issue of Viewpoint, Caterpillar collaborated with Circadian Technologies, Inc., an international firm that helps companies manage shift-work and extended hours, to develop “Managing a Mining Lifestyle,” a DVD to help machine operators and their families better cope with the lifestyle required of those in the mining industry. The video provides practical solutions for easing the adjustment and day-to-day challenges associated with mining lifestyles. DVDs are available through Caterpillar dealers by requesting media number TEVD6360. In addition, Caterpillar co-authored a white paper on operator fatigue and fatigue monitoring technologies; it can be found in the Safety News section on [safety.cat.com](http://safety.cat.com).
CAT DEALERS TO DISTRIBUTE PAVING ALTERNATIVE

Caterpillar and Claycrete Ltd. have entered a marketing agreement to provide an innovative paving solution for mines, oil and gas sites, municipalities and other industries. Cat dealers will have exclusive rights to market Claycrete products worldwide, while Caterpillar Global Mining will support and oversee the business. Based in Perth, Australia, Claycrete’s unique process combines project management and proprietary chemicals to transform native soils containing clay and/or limestone into pavement-like roads, site pads or solid bases for paved roads. The result is weather-resistant, long-lasting and environmentally friendly.

CAT GLOBAL MINING HOSTS MINERS’ FORUM

More than 50 customers representing 44 companies attended a recent Caterpillar Miners’ Forum in the Costa del Sol region of Spain. The event also brought together 48 dealer sales professionals from 18 dealerships. Participants had an opportunity to learn about efficient practices for equipment productivity and participate in a wide variety of interactive breakout classes led by Caterpillar experts. Topics included sustainable development, new product initiatives, software tools, training and development strategies.

CAT-SPONSORED ROBOTIC VEHICLE TAKES 1ST

The Caterpillar-sponsored robotic vehicle of Carnegie Mellon University earned first place at the 2007 DARPA Urban Challenge. The event featured autonomous ground vehicles maneuvering in a mock city environment, executing simulated military supply missions while merging into moving traffic, navigating traffic circles, negotiating busy intersections and avoiding obstacles. The challenge is sponsored by the Defense Advanced Research Projects Agency to help develop a fleet of autonomous ground vehicles to improve troop safety. As part of the sponsorship, Caterpillar provided advanced technologies such as drive-by-wire steering, sensing and software. In addition, Caterpillar has an embedded engineer working full-time with the university’s team. Also receiving high honors was the Caterpillar-sponsored Virginia Tech vehicle.

NEWS FROM CAT

Gearing up for MINExpo—September 22-24, 2008

Once every four years, the entire mining world gathers in Las Vegas, Nevada, USA, for MINExpo. Sponsored by the National Mining Association (NMA), MINExpo is the industry’s premier showcase for companies specializing in every facet of mining. Caterpillar’s booth at the Las Vegas Convention Center will be even more substantial than in 2004. For more details, talk to your local Cat dealer or visit the National Mining Association’s Web site, MINExpo.com.

FILTER SYSTEM E ARNS EPA APPROVAL

The Caterpillar Diesel Particulate Filter System for off-highway machines has earned Level 3 conditional verification from the California Environmental Protection Agency Air Resources Board. The verification formally recognizes the passive filter system as effective and reliable in achieving at least an 85 percent reduction in particulate matter exhaust systems. The system also meets the California 2009 regulation governing nitrogen dioxide emissions. It features a passive regeneration system to automatically remove particulate buildup. The filter requires no downtime to regenerate and no external heat source or fuel source.

NEW WHEEL LOADER, TOOLCARRIER DELIVER HIGH PERFORMANCE

The new Caterpillar 938H wheel loader and IT38H with integrated toolcarrier linkage feature the Cat C6.6 engine with ACERT® Technology for responsive power and low emissions. The new engine, differential lock system, load sensing hydraulics and increased lift and tilt forces deliver high performance in digging and material handling applications while limiting engine emissions to meet U.S. EPA Tier 3 off-highway emissions regulations and worldwide emissions standards. The loaders also have new features that aid machine health monitoring and service, including an in-cab messenger display that provides real-time machine performance, engine and diagnostic data.

ASSET MANAGEMENT SOLUTIONS TO BE STANDARD

Caterpillar will equip most of its new core, mining and industrial machines with EquipmentManager and Product Link—the remote asset management solution developed by Caterpillar. The remote tracking and management system will be a standard feature in the United States and Canadian markets. Caterpillar has provided remote asset management capabilities as an option since 1998; now Cat will deliver these capabilities as an integral part of most core Caterpillar machines. Product Link will be available as an option for the remaining Caterpillar machines. Caterpillar will phase in EquipmentManager / Product Link beginning with wheeled hydraulic excavators and articulated trucks. The remaining machines will be phased in throughout 2008, arriving to dealers and customers with Product Link as standard equipment, along with a three-year subscription to Asset Watch, the remote asset management portion of EquipmentManager.

CAT ACQUIRES TUNNEL BORING COMPANY

Caterpillar recently entered the rapidly expanding tunnel boring machine business with the acquisition of leading global manufacturer Lovat Inc. Caterpillar considers the acquisition an excellent strategic fit and plans to leverage its global business with continued investment in the Lovat product line. Lovat customers will benefit from the strength of Caterpillar’s global purchasing organization, from its research and development initiatives, Caterpillar’s global reach and its experience in large-scale manufacturing processes. Lovat’s tunnel boring machines have a reputation for durability, reliability and performance while working in some of the most demanding applications.

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