Caterpillar MineStar team / MINING SOFTWARE

Technology is at the forefront of mining, now more than ever. Caterpillar is certainly no stranger to the mining industry, nor technology systems. The company has a deep-rooted history with innovative technology systems that have changed the face of mining over the past few decades. There are countless individuals at Caterpillar that have contributed to the Cat mining technology solutions oftoday, but a key group of people have been involved for literally decades, bringing early thoughts and brainstormed ideas that began on paper to life in mining applications. This group is nominated for induction into the International Mining Hall of Fame: Mining Software Category.

Nominees: Craig Koehrsen, Michael Murphy, Chuck Sahm, Carl Hendricks, Claude Aboujaoude, Jason Gough, Josh Bynon and the late Chuck Boen. Together, this group of exceptional candidates has over 45 patents and 150 combined years of technology innovation at Caterpillar.

The group continues to work on state-of-the art Cat technology solutions today. From the early days ofGPS and data collection systems, these people revolutionized the machine control and guidance sector with the advent of the VIMS and Terrain systems (formerly known as Computer Aided Earthmoving System (CAES) and AQUILA Drill – the latter work by 2015 Surface Mining inductee Jonathan Peck). These early technologies provided a foundation for Cat technology systems today, including comprehensive surface and underground automation technologies at work in mine sites around the globe. These systems that have now joined forces make up Cat MineStar, the mining industry'sbroadest and most comprehensive suite of technology products on the market today.

Nearly 30 years ago, a small group of three people were tasked with revolutionizing the way data was captured and transferred on Cat machines. This product, soon to be known as VIMS™, was the first product to use Windows in an off-board application as opposed to the very popular DOS systems of the day. VIMS had more computing power than the moon missions at that time, and this cutting edge technology, generations later, is still a foundational data system on Cat mining machines today.

The use of GPS was the next major milestone for Cat technology products. As one of the first companies to utilize GPS in machine control systems, Caterpillar was again leading the industry with technology. Decades later, information systems and bandwidth have evolved tremendously and Caterpillar has been ready to adapt that evolution every step of the way. In 1996 Caterpillar debuted the first autonomous truck at MINExpo. At the time the mining industry was not ready for such a radical change, so the team kept working to perfect the system until the market was ready to adopt. Currently, Cat autonomous trucks are operating at six mines and a test fleet at the Arizona Proving Grounds. Caterpillar is activelypursuing the vision for a fully autonomous mine site.

Today, MineStar is behind the largest single autonomous truck fleet in the world, that employed by Fortescue Metals' Solomon iron ore mine in Western Australia. Today that fleet comprises 70'Command for hauling' Cat trucks.

Through MineStar, sophisticated on-board intelligence and advanced guidance technologies make it possible for these 227-t trucks to maneuver through mine-site traffic, back into loading points andnavigate to dump sites—all without human intervention. Mining customers have over 130 Autonomous Cat trucks in operation and have moved close to 1 billion Tonnes of material, and Fortescue has stated a 30 % increase in productivity along with a reduced cost per tonne

compared to its standard fleet of trucks. For nearly four years, Caterpillar worked with Fortescue to make this fully autonomous haulage fleet a reality. But the journey to autonomy took much longer than that. Mining automation has long been a goal for Caterpillar, and it took a team of smart, dedicated people to achieve that goal.

More than autonomous trucks

The Cat autonomous trucks system makes full use of the Fleet capability set of MineStar. Fleet is the scheduling-and-assignment and materials tracking system that makes best us of sophisticated algorithms, which are updated with real time information, to determine the optimum assignment and route of each truck. Of course the system also tallies and reports production and productivity of each asset. Fleet also is in use at many mines using operator-controlled trucks. In addition to optimizing routes and ensuring material goes to the right place, Fleet has proven effective in reducing shift-change delays and in optimizing refuelling schedules.

In addition, Fleet can simulate mining truck productivity and estimate cost per tonne on various haul road profiles. Mines can use these tools to determine if mining trucks are achieving predicted speed on grades, as well as cycling and waiting at the loader in predicted time ranges. With this data, operation managers can investigate possible causes behind delays—Are rough or slippery roads or tight corners forcing operators to slow down? Is rolling resistance higher than planned? Is visibility poor due to dust or obscured views?—and make the necessary adjustments.

The Detect capability set of Cat MineStar includes a range of object detection technologies to enhance safety by guiding operators as well as autonomous trucks. In its fullest form, Detect offers proximity awareness, in which machines communicate with machines to ensure proper space is allowed at all times.

The Health capability set monitors and records information from sensors on each mining machine and reports anomalies. Of course the system generates summary reports that turn data into useful information, which enables planned maintenance and repair scheduling.

Application of MineStar extends to many types of equipment. For instance, the dozer, so associated with Caterpillar, is a hardworking machine essential in a multitude of operations. But many of these applications can be hazardous to operators — like under highwalls, near slides or pushing to underground feeders in stockpiles. Even in stable environments, the act of operating a dozer takes a toll. Operators face continual full body vibration and regular exposure to dust and sand.

Caterpillar now offers, under the Command capability set of MineStar, three different remote control systems for dozers. Line-of-sight systems include a portable console carried by the operator and a remote operator station, which can be truck or trailer mounted.

Additionally, a teleremote system using video cameras and audio feedback enables a dozer operator to be stationed practically anywhere. And recently the Cat semi-autonomous dozer operating system has been proven at a coal mine in Wyoming where one operator remotely oversees four D11T dozers. The system is highly productive. Additional semi-autonomous dozer systems are operating at two mines sites in Australia.

Cat Terrain for drilling is another capability set of Cat MineStar. Terrain for drilling keeps operators in the cab, improves drilling accuracy, provides feedback on variations in bench geology, tracks drill and operator productivity, and allows remote, real-time supervision of drilling activity and blast planning.

A semi-autonomous system, Command for underground automates the tramming functions of LHDs. The operator can control one or more machines from an office or remote location, enhancing safety and optimizing production between multiple machines.

What has been achieved with MineStar is quite remarkable. The capability sets— Fleet, Terrain, Detect, Health and Command—can be used in combination or individually to allow operations the flexibility and scalability required to be more productive, efficient and safe.

For current Cat MineStar information, see: HTTP://cat.com/minestar