Cat® Shearer Automation

Enhanced Horizon and Extraction Control Functionality

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1 Abstract

Today's longwall mines are safer, more productive and more efficient than ever before thanks to improve-ments in automation. Over the years, longwall machinery has grown more and more complex, forcing manufacturers to optimize interaction between systems and machines like roof supports, conveyors, beam stage loaders and shearers. To evaluate this progress, mine operators intend to spend more effort on analysis and optimization —which means they need comprehensive data and information on these systems.

In this context, the shearer plays a key role. As the cutting machine, it dictates the rhythm of production and face advance. If the shearer is operated at productivity, all other longwall sub-systems have to follow efficiently. Other motivations for increasing the automation level of a longwall system are the following:

- Efficiency – maintaining a balance between production achieved and effort spent
- Further sustainable use of equipment with longer availability
- A constant utilization level of the equipment and prevention of overload situations, allowing for more effective planning of maintenance activities and intervals
- Increased safety

Shearer automation means reduced working time for operators near the cutting machine and at the face in general. Today, it is possible to run a shearer with only one operator instead of two, meaning no operator has to leave the fresh air stream. Furthermore, the operator can leave the machine to itself in defined periods of the mining cycle and wide areas of the face. People spend less time in dangerous areas and are less exposed to dust and noise.

2 Shearer Control System

It takes three key components to realize this level of automation: A modern and contemporary control system like the Cat PMC® Evo-S, intelligent software modules, and a wide range of high-quality measuring technology. The PMC Evo-S is a powerful, modular, Ethernet-based control system that allows for a modern programming style—meaning that it can be used to implement complex algorithms and functions. The system is uniquely designed with a large number of intrinsically safe components, which makes it system easy to maintain at the face without opening flame-proof enclosures.

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3 Intelligent Software Modules

Caterpillar officially distinguishes between different levels of shearer automation, from basic to advanced.

Each of our shearers is equipped with a basic automation package. This package allows the machine to be operated by remote control, and to switch all equipment safely while monitoring operation. This package also includes some automation logic that can reduce overload situations, as well as some diagnostic tools for troubleshooting and problem-solving.

	Manual operation	**provide manual operation: only PLC**
Basic Control	Shearer Radio Control Software	allow miner to operate the Shearer viaRadio Control
	Standard Display	provide the visualisation of the operation related values and parameters
	Self Monitoring	permanently check of all operation related components and functions
	Safty Functions	Tilt Sensor Monitoring in Radio Handheld, Monitoring of the Radio Connection etc.
	Speed Limiting	definition of up to 10 Speed zones along the face
	Display / HMI Tools	for Miner-Machine Interaction
	Cutter Motor Feedback	Controled breaking of haulage speed depending on cutter loadBasic Control
	Onboard System Diagnostics	for easy trouble shouting

Alternatively, we offer two more complex automation packages: Automation Control and Advanced Automation Control.

Automation Control includes some important features, including extended Gate End Communication, which provides data exchange with other Longwall components. This automation level allows the ranging arms to be operated in a high-quality closed-loop operation for precise steering. It also provides a collision avoidance function to prevent collision between the shearer and the shields operated by a Cat PMC®-R.

The most important feature is State-based Automation (SBA). SBA allows definition of the full cutting cycle of the machine along the face for both cutting directions between main gate and tail gate, as well as the cleanup operation at the gate ends. It is important to specify automation parameters like cutting height, speed and cutting mode, all of which can be defined in up to 40 different zones along the face. This is called zone-based automation.

Automation Control	**Basic Control +**	**advanced automation of low accuracy using inclinometers: PLC and IPCAccuracy < 100mm along the machine length**
	Gate End Communication	provide data exchange with other Longwall components
	Collision avoidance	prevention of collision between the Shearer and the shields
	State Based Automation (incl. Zone Based Parameters)	defnition of automation parameter in zones along face: up to 40 different zones
	Ranging Arm Closed Loop Control	for exact ranging arm position control
	Cuting Modes	Allows to operate the Shearer via radio control

Drawing on decades of experience in shearer automation, we have created several preset cutting modes that can be chosen in each automation state.

Advanced Automation Control is Caterpillar's answer to customer requests, bringing us closer than ever to fully autonomous shearer operation. This package includes a feature called LongwallNavigator, which combines Cat software tools in the gate ends and in the shield controllers into one package that offers advanced geometry and trigonometry calculations for full 3D navigation, as well as an advanced floor profile calculation and a high level of sensor technology.

Advacned Automation Control	**Basic Automation 1 +**	**advanced automation of high accuracy using usingInertion Navigation: PLC, IPC and IMU Accuracy< 20mm along the machine length**
	Advacned Geometry / Trigonometry	for 3D Navigation
	Floor Profle / Arm Algorithms	Horizon Control, Extraction Control and Face Alignment
	Interface to Longwall Navigator / Landmark	enables integration of third party navigation system with Landmark interface

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These technologies make it possible to achieve Horizon Control, Extraction Control and Face Alignment. Extraction Control allows the machine to follow defined floor and roof profiles along the face, better following any given coal seam undulations for optimal extraction and production. At the same time, Horizon Control guides the machine to follow the seam undulations in the direction of the machine's advance. Face Alignment keeps your face straight for consistent production and minimal wear of the conveyor system.

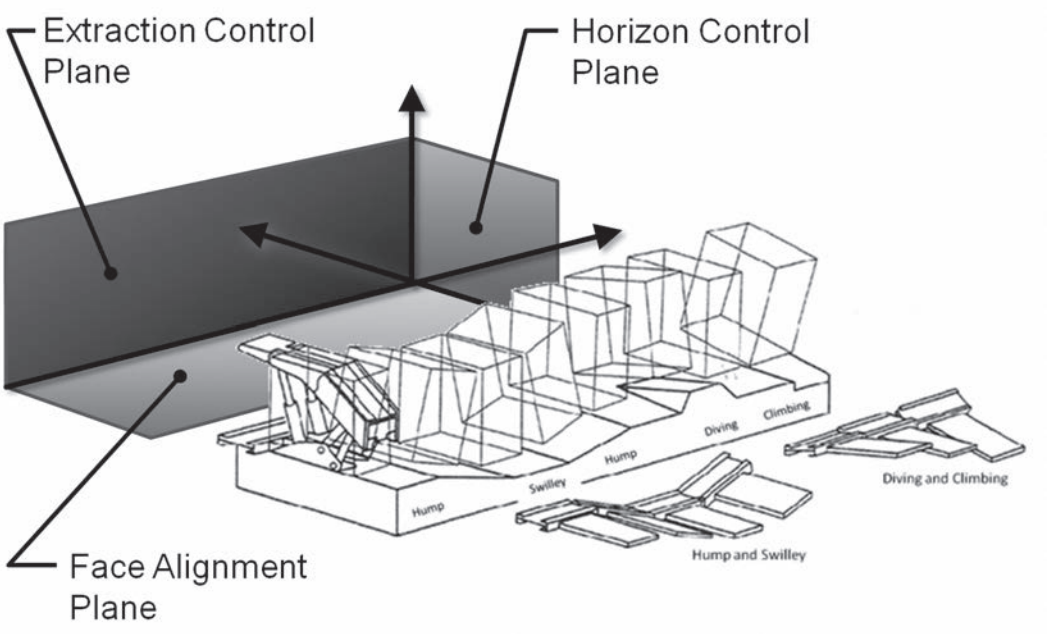

Figure 2: Horizon Control, Extraction Control and Face Alignment are the main features provided by Cat LongwallNavigator.

All these automation features support both uni-directional and bi-directional mining methods. We can also support additional customer-specific automation processes, including complex LTCC operation in combination with fully automated roof supports. In that case, the PMC Evo-S control system provides continuous information to the PMC-R roof support controls to steer the face conveyor push operation. This is the heart of Caterpillar's high level of subsystem control integration.

SBA is the most successful and efficient tool for defining and controlling complex automation cycles. It allows the shearer to operate precisely according to the operator's defined production process—including directions, speeds, arm heights, cowl positions and ranging arm control modes. Users can define up to 500 states with actions and conditions to be met before the next state is entered. The system is also capable of defining up to 40 zones along the face for each of the zone-based parameters. This allows mine personnel to determine all imaginable variations in longwall operation cycles.

4 History & Technology Behind Advanced Automation

Automated horizon control has been a goal for the longwall mining industry for years. There have been systems developed for shearers that use a reference cut in one direction and extraction to a desired thickness in the opposite direction. These systems have been enhanced over time with on-board calculations that take into account machine and face angles. This helps create greater accuracy in actual extraction parameters with various methods of extraction depending on the cutting sequences being employed on the face.

At the turn of the century, modern inertial sensor technology was introduced to offer accurate measurement of the face alignment, horizon angles and pan profiles of longwall faces. Originally derived from gyroscope technology, inertial sensor developments became a big focus for Bucyrus and DBT, both of which were subsequently purchased by Caterpillar. The inertial sensor technology now used by Caterpillar has been developed by a third party supplier, while the associated software was developed by Caterpillar over the past 14 years.

Caterpillar's proprietary system has been continually improved since its implementation, and saw improvements to the software, hardware and monitoring systems with integration into the Cat visualization suite of programs as part of Cat MineStar Health.

HARDWARE

Caterpillar offers a couple of proprietary inertial sensors to use as Inertial Measuring Units (IMU). These units have proven their capabilities in underground longwall mines in Australia. These unites are classified by accuracy, ability to detect North and the ability to process data onboard. Each unit is configured to operate within the system, and customers choose whichever unit best meets their needs.

SOFTWARE

As part of the proprietary Navigator system, there is a processor (IPC) on the shearer to collect, process, calculate and communicate data within the shearer EIP control system, as well as both to and from the gate end computer. Face and Horizon profiles are generated by the IMU, through the IPC to the visualization software (VShearer, a part of Health for Longwall) at the gate end. With this system, there is no need to transfer data to a surface server for processing, and all communications are carried out between the shearer and gate end visualization PC.

The ranging arm and shearer positions are calculated by the PLC. The IPC performs the automated steering—including state automation—and sends haulage and ranging arm commands back to the PLC.

Figure 3: Example Cat Shearer main display while in operation

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ACCURACY

The latest information received from an Advanced Automation Control longwall operation in New South Wales, Australia, shows that accuracy has been measured to within 50mm. The original target was to be accurate to within 75mm, but some enhancements to the software have resulted in this greater accuracy.

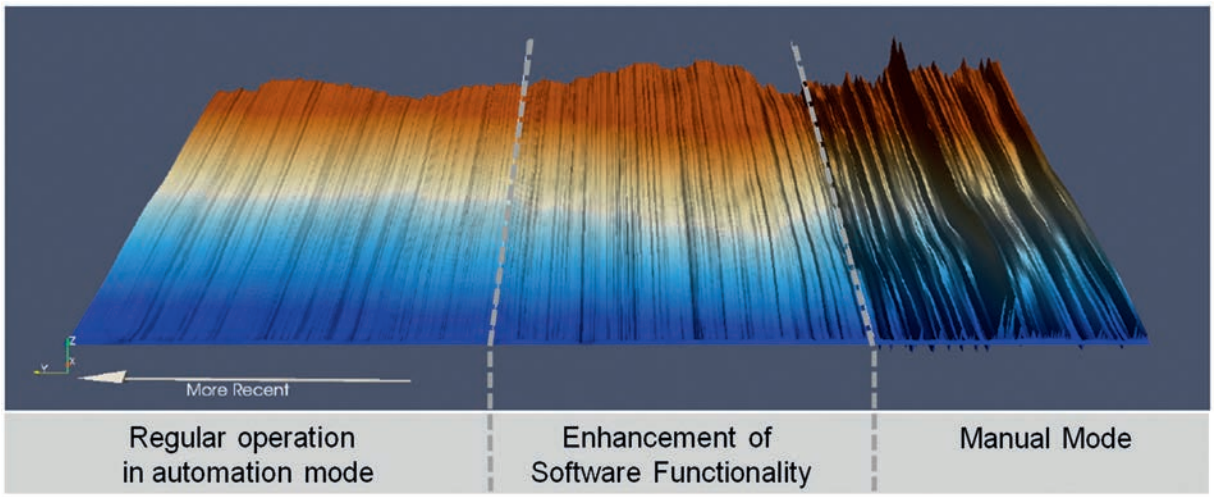

Figure 4: Improvement of profiling during implementation at example mine site

The graphic in figure 4 shows the change in the profiles over three months during implementation of shearer automation at a mine site. The degree of automation was increased in two major steps and the period of manual override constantly reduced.

[1] As at the date of creation of this document, the intellectual property rights in the LASC technology (Interconnection of Landmark Compliant Longwall Mining Equipment-Roof Support System Communication) are owned by the Commonwealth Scientific and Industrial Research Organization. LASC technology is used and distributed by Caterpillar under license.

5 Does Automation Mean Complexity?

Once the system is commissioned, running in automated mode is simple. The motor's start sequence is a two-button operation on the handheld remote, and it only takes two more buttons to activate AUTO mode. The shearer will then initiate the drum mode for the desired state and position the drum using the calculated data. These calculations are done on-board in the IPC using IMU data, shearer position data, measured and fixed dimensions of shearer geometry, ranging arm position and cutter drum diameter.

How do we get to a higher level of automation?

Of course, to set up all of this automation requires a fundamental understanding of the longwall mining process and technical expertise with regard to the mechanical and electrical equipment, as well as the electronics. Usually, personnel on-site are already familiar with most of this equipment from their current operations, but they are often eager to take their knowledge to the next level. These personnel must be trained to use the new technology, but companies also need to roll out a new culture for automation to truly take hold. Automation needs to be understood as something that enables and supports existing workers rather than a potential cause for displacement of jobs. If anything, increased production will ultimately increase the workload one-site, even if the tasks are different with an automated system.

To set up the system into higher-level automated modes, Caterpillar offers comprehensive tools to allow the operator or the crew to define the requirements by use of intuitive menus.

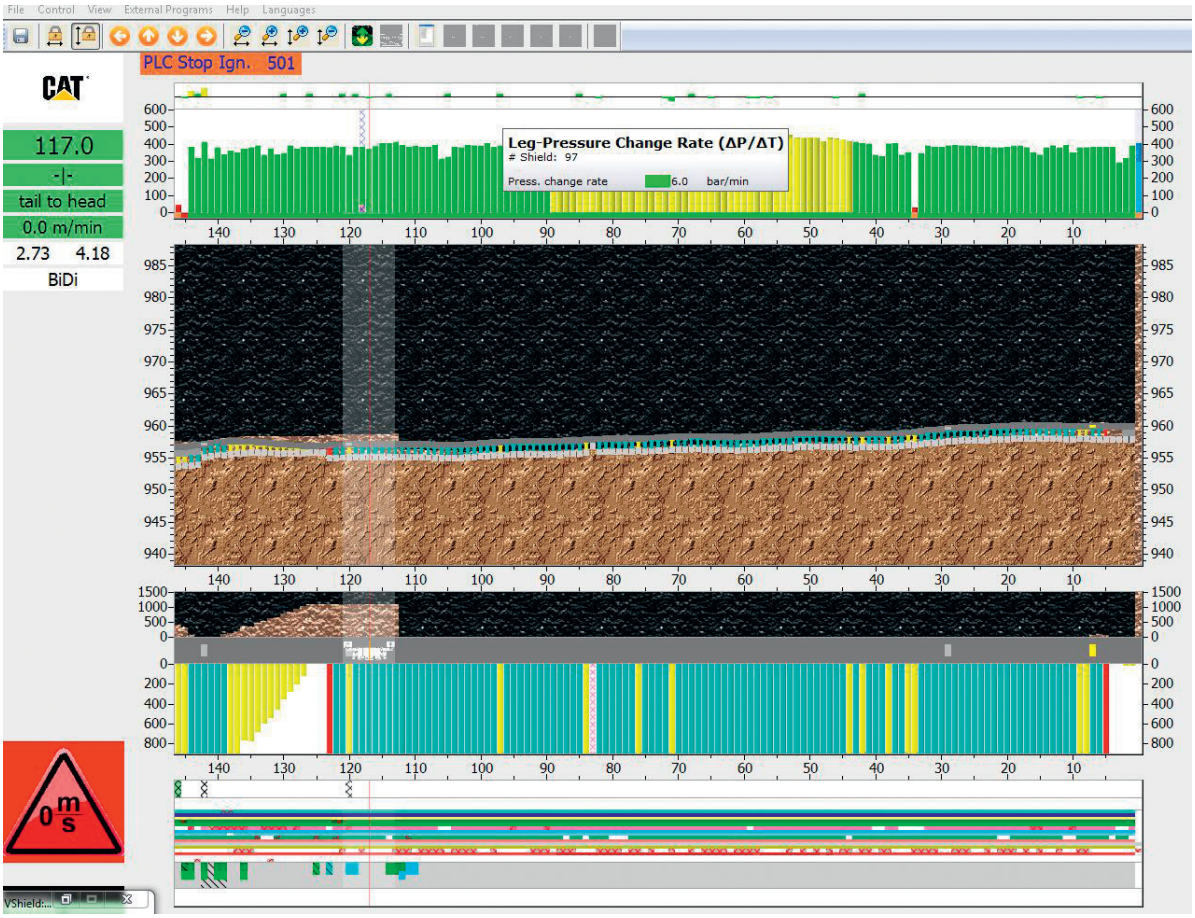

Figure 5: Cat MineStar System VShield (shield visualization program) allows users to define Face Advance Profiles and provides the operator with a realistic view of the face alignment profile

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Data handling—for example, loading parameter settings and state tables onto the machine—is fast and easy. Caterpillar's experience is that within a few weeks of implementation (if not during the commissioning phase) operators adjust the state tables even once or twice a day without complaint, easily finding the optimal settings for the production cycle of their longwall operation.

Caterpillar's comprehensive set of software tools supports them in their efforts to analyze the latest operation cycle. These software tools make up Cat MineStar Health for Longwall, and are used at the gate end PCs and on the surface.

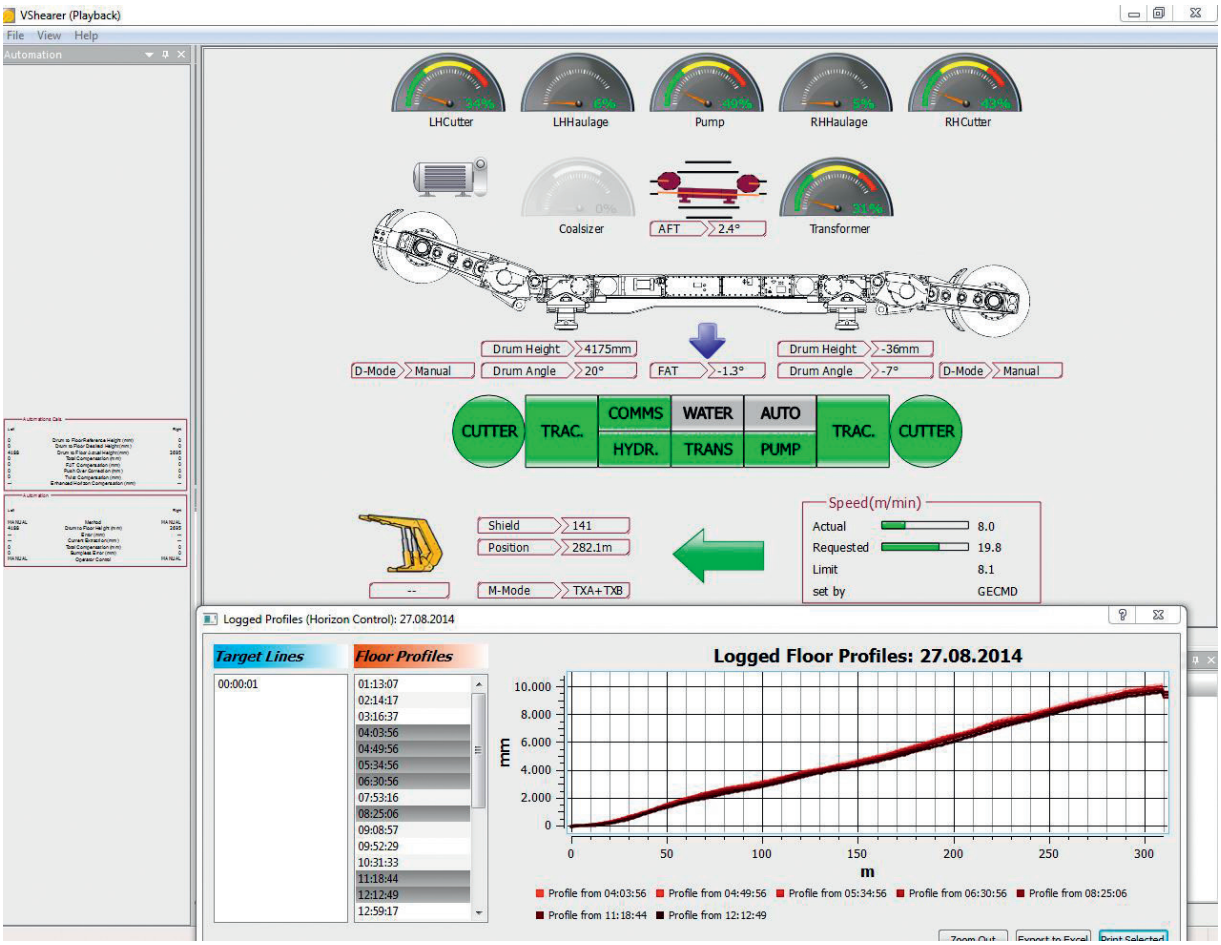

Figure 6: Cat MineStar System VShearer (shearer visualization program) allows users to define Extraction Profiles and provides the operator with a realistic view of the actual pan profile

In particular, these tools allow the visualization of all longwall subsystems an equipment—from shields, AFCs, shearers or plows to chain tensioning and boot end systems—with regard to machine variables and parameters. Health for Longwall offers live views, generates daily log files for analysis and plays back operational data. Using the Cat Data server for longwall (VDataSrv), the mine team is able to provide all relevant live data at five different software interfaces (OPC, Sql, UDP, EIP and a Web server) within the mine LAN, giving the mine further usage of the data within their network.

As our latest development, Health for Longwall includes VlongwallDataBase as a powerful tool for longtime data storage and reporting of almost all data sets generated onboard. This allows the mine operators and the supporting dealer to run continuous reports and analysis on the machines' health, supporting proactive maintenance work at the face. Health for Longwall vibration analysis offers continuous online vibration monitoring. Use of this tool allows the detection of all abnormalities in the longwall system's inherent drive train, such as bearing defects or increases in wear.

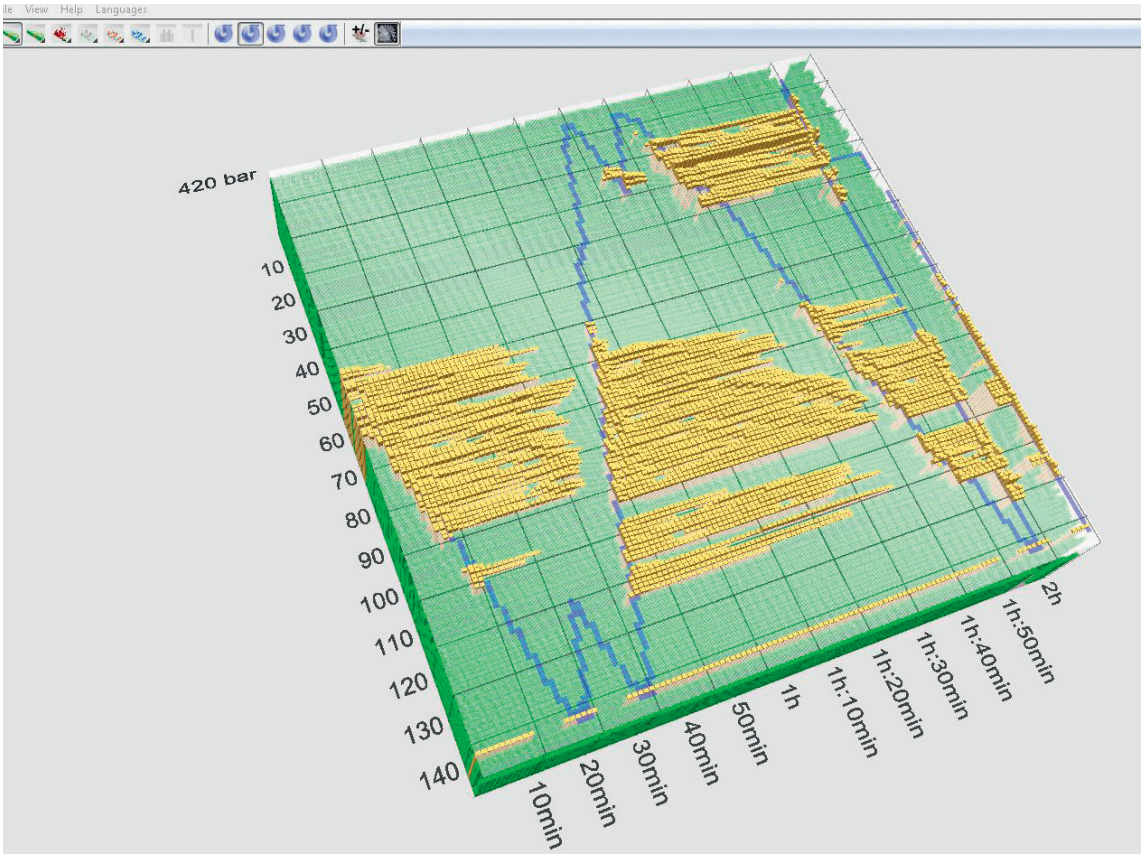

Figure 7: Cat MineStar® System - VGraph3D providing several 3D waterfall plots for review and predictive analysis showing e.g. set pressure or other parameter plotted over time and face width

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6 Serving Production Expectation

State-based automation and Navigation features help production smooth at a consistent rate and allow the mine a high and constant coal-clearance capability. Downtime of equipment is reduced and inefficient use of uptime is avoided.

Of course, the use of state-based automation requires strict discipline, a cultural shift and a concerted effort by management to steer the change. But considering that the results can double-digit productivity increases, these investments in time and effort pay off quickly.

When Cat SBA was implemented at a mine in Australia's Hunter Valley in 2004, the success was immediately apparent. In the first calendar month after introduction, productivity increased more than 10 percent, and it has remained at a consistently higher level since the introduction of SBA.

Pre-SBA production averaged 1,892 tonnes per hour, whereas the average production rate after SBA introduction was 2,315 tonnes per hour. And since the installation of SBA, the EL3000 has been the highest-producing shearer in Australia. In 2008, four of the top five producers in Australia were using Cat EL3000 shearers with state-based shearer automation. And the story goes on: In spring of 2014, Caterpillar had another customer in Australia exceeding planned production month by month.

The utilization of the fully automated shearer is now consistently reaching more than 94% with no input from operators. This number is expected to reach 100% as operator confidence in the automatic steering system grows.

Notes

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Notes

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