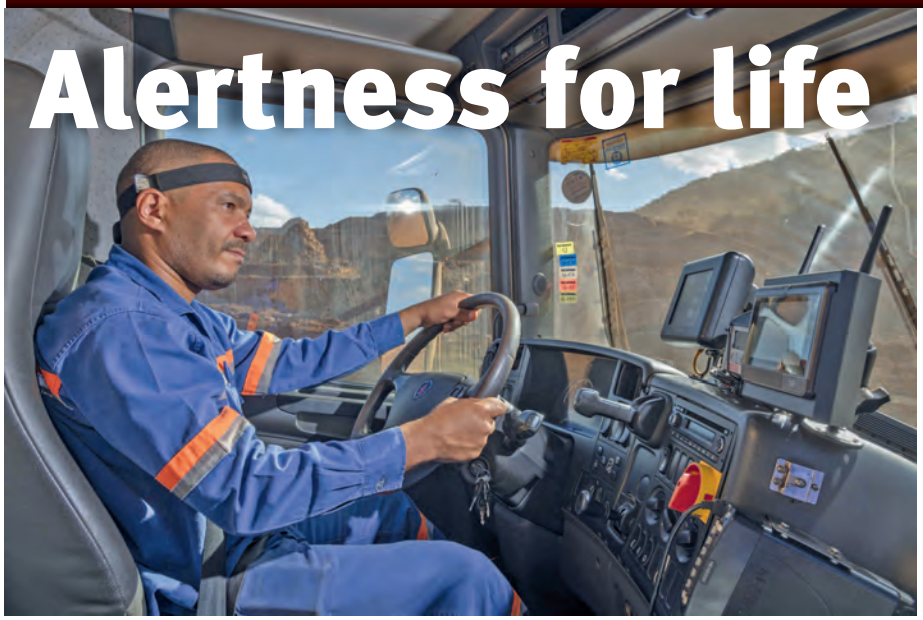
Alertness for life



Mechanical engineer Odilson Ribeiro wearing a fatigue monitoring SmartCap at Anglo American's Barro Alto nickel operation in Brazil

Fatigue monitoring in mining, both reactive and predictive, has moved well beyond a few trials and first adopters. It is now seen as an intrinsic part of most major mine health and safety plans and is helping instil a new culture of managing tiredness and drowsiness among operators, reports Paul Moore

In mining fleet fatigue monitoring, there are so-called predictive (some technology providers prefer to call the more comprehensive versions proactive) systems that warn operators of the increased likelihood of a fatigue related event such as those based on wearables monitoring sleep data, eye movements or even voice monitoring carried out pre-shift; and reactive systems that monitor operators in real time in the equipment cab then react to a microsleep incident having occurred or about to occur – these are mainly based on cameras monitoring eye and head movements.

While in the past, operations tended to mainly look at reactive systems as immediate action to try to bring down fatigue related incidents, today, most operations are moving towards having a combination of both – with fatigue monitoring becoming much more part of the overall minesite health and safety plan and management approach – control of fatigue is increasingly seen as just as important as wearing PPE or testing for drugs and alcohol. This is reflected in the fact that most mining company sustainability reports now mention fatigue monitoring specifically.

The industry has also moved on from just conducting a few exploratory trials here and there, to choosing one set of technologies and rolling it out across the entire fleet. There remains some use of different technologies at different minesites within the same mining group – while others have opted to standardise across all their operations – Newmont using Caterpillar's Driver Safety System (DSS) worldwide being a good example.

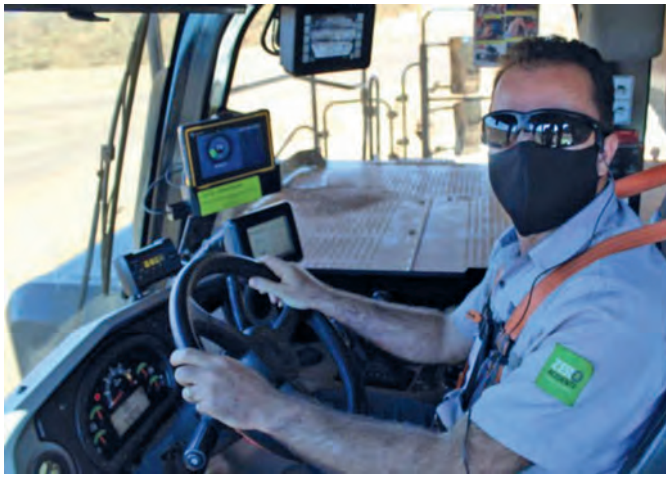
These trends have also been reflected in technology provider activity; with major players acquiring fatigue monitoring technology companies or at least deepening partnerships, so as to be able to offer mining clients a fatigue monitoring solution as part of a package that mayalso include collision avoidance systems, fleet management systems etc. Hexagon as an example acquired Guardvant and its leading OAS reactive system in 2018, but in May 2021 also signed a partnership with Fatigue Science to offer its Readi platform for predictive fatigue management globally. Caterpillar owns the technology and IP for DSS in mining, part of its MineStar™ Detect portfolio of safety technologies and services but still works with the original developer Seeing Machines on R&D . It also uses Fatigue Science technology in its Smartband wearable predictive offering to complement its market leading DSS reactive system while Fatigue Science recently rolled out its ReadiWatch offering, replacing its ReadiBand. In May 2021, Hitachi-owned Wenco acquired another industry leader, SmartCap, which uses electroencephalogram (EEG) monitoring to assess fatigue levels either in a cap/hard hat and/or wrist Lifeband as part of its overall Life fatigue management solution.

Finally, as the industry has evolved, the focus has moved from the heavy mining trucks to light and other vehicles on minesites – these fatigue monitoring systems tend to be simpler and with less hardware, but also cheaper, due to there being much larger numbers of vehicles involved. But they are based on the same technologies. In October 2020, Caterpillar entered into an agreement with Seeing Machines to deliver and support light vehicle and on-highway driver fatigue and distraction monitoring technology through Cat® dealers. Just like DSS, Seeing Machines' Guardian 2 system is an advanced, non-intrusive system that senses operator movements and analyses them for symptoms of fatigue or distraction in light vehicle applications. Seat vibration and audio alarms alert operators when a microsleep or distraction event is detected to effectively reduce dangerous and costly incidents. Hexagon offers its HxGN MineProtect Operator Alertness System for Light Vehicle or OAS-LV. Rollout of the light vehicle systems is still patchy, largely because the perceived need by mines is not as great given that unlike the mining trucks these vehicles are not being operated for 8 or 12 hour shifts, plus it is complicated by the fact that many of the these non-primary fleet vehicles are operated by contractors or other service providers. But the comprehensive use of fatigue monitoring across all vehicles in mining is inevitable as an important part of ensuring safety.

MUSA relies on Optalert

One of the fatigue monitoring technologies that has been in mining and other industries for the longest period, and which remains independent, is Australia's **Optalert** – a technology commercially available since 2008 which grew out of the research and clinical trials of Dr Murray Johns, a world-renowned authority on sleep medicine. During his 40 years as a clinician, Dr Johns developed a special interest in the state of drowsiness and its associated dangers for people whose very lives depend on them remaining awake at the appropriate time. While in recent years its major focus has been on systems measuring drowsiness or wakefulness for pharmaceutical drug trials, mining is still a key market for the company.

Optalert's drowsiness detection glasses work by measuring the velocity of the operator's eyelid 500 times a second using a tiny invisible LED built into the frame of the glasses. "Core to the success of our wearable technology are two key measurements tracking the amplitude velocity ratio - essentially measuring how fast and how far a person opens their eyelid after they close it." These are translated into a score measured on the Johns Drowsiness Scale (JDS), which the operator sees displayed on their indicator or processor positioned in the cab.



Operator at Mineração Usiminas (MUSA) iron ore mine in Brazil using Optalert glasses -based fatigue monitoring system

Over the years, Optalert has been deployed either in trials or larger rollouts by mining groups including Newgold at its San Xavier operation in Mexico, BHP's Mount Keith, Spence and Escondida and Vale's Carajas as well as by mining-related bulk transport companies like Bis Industries and Toll. Its most recent rollout in mining is at the iron ore mining operations of Mineração Usiminas (MUSA) in Minas Gerais, Brazil. MUSA recently stated: "Through the Optalert device installed in glasses, the stages of tiredness are checked. From then onwards, visual and audible alerts are issued inside the cabin of the equipment itself and also in the monitoring centre, where there is a controller designated for this. The angle of the operator's eyelids is measured, with real-time monitoring, as soon as he starts operation on the work shift. From these measurements, a specific and calibrated fatigue scale is generated for each one, ranging from zero to 10: from indicator 4.5 it is considered a state of attention and, above 5, critical. The controller interacts with the operator, acts preventively to alert him and assesses the situation: the measures adopted include signalling to the supervisor the need for the operator to stop the activity, exercise at work, have a moment of rest or even the relay." Today, MUSA has 114 off-road truck operators using the Optalert system and counting.

Cat DSS filtering down through the industry

Caterpillar's DSS, supplied both direct and through its dealer network, continues its global market leadership in mining fatigue monitoring – first and foremost through relationships with Tier 1 miners – Newmont as stated standardised on DSS some time ago while others like Rio Tinto, Barrick and Newcrest also use the system across multiple sites.

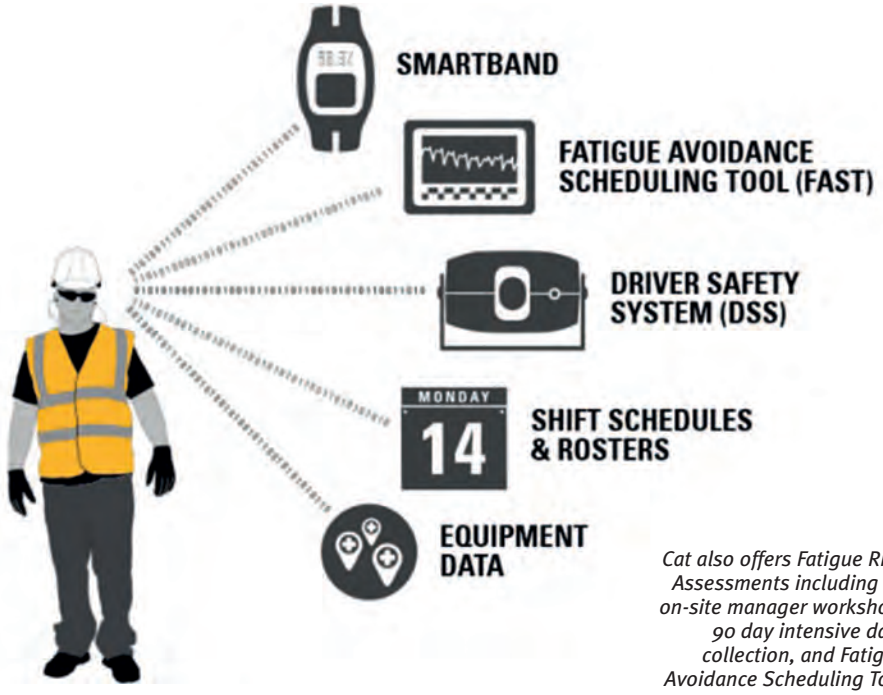
A good recent example of a DSS rollout is at Barrick's North Mara. The mine contacted Cat dealer Mantrac to help resolve a recurring issue on their site. They were witnessing 12 accidents per year, including one where an operator was driving a truck that rolled over and injured him. Mantrac suggested and implemented state-of-the-art DSS fatigue detection technology via a comprehensive change management program for the site. Mantrac designed a total safety and productivity solution that engaged 90 operators of 15 trucks over a three-month transition period. This included reactive and predictive solutions. With custom smartbands, operators were able to manage sleep and fatigue. The trucks were also fitted with DSS to detect microsleep events and alerts the operator with an audio signal and seat vibrations. A recording of the event is also sent to a team dedicate to managing health and safety on the worksite via SMS. "By detecting eyelids closing, eyeball movements, chin orientation and distraction events, this technology from Mantrac caught instances of distracted driving, microsleep, speeding and more. The management received daily incident reports from Mantrac consultants, in addition to data dashboard access."

Caterpillar is also having successes with many mid-tier operators. To give some examples over the past few years – Eldorado Gold has deployed the Cat DSS fatigue system across all the mine haul trucks at its Kisladag operation in Turkey, which includes install on 14 Cat 785C & 10 Hitachi EH4000 models with the system in use since April 2021. At the Pavlik GOK gold mine in Russia's Far East Magadan region, nine Komatsu 91 t class HD785-7 dump trucks operated by contract miner Detra LLC have been equipped with DSS. This decision was made based on the results of testing, which was carried out on five dump trucks over three months, from January to April 2020.

Another good developing world mining example is in Laos at two mines owned by PanAust Ltd. "At PanAust, our commitment to safety is underpinned by our Zero Harm philosophy whereby all incidents are considered preventable," says David Reid, General Manager Operations. "The Driver Safety System supports our commitment to keeping people across our operations safe."

PanAust's operations in Laos are operated by Phu Bia Mining Limited (PBM), which is 90% owned by PanAust and 10% by the Government of Laos. PBM operates two open pit mines within PanAust's Phu Bia Mining Contract Area in Laos, approximately 190 km north of Laos' capital city, Vientiane: Phu Kham copper-gold operation and the Ban Houayxai gold-silver operation.

The loading and hauling operations at Phu Kham and Ban Houayxai consist of face shovels and excavators loading Cat 777D 90 t (100-ton) trucks — 53 at Phu Kham and 11 at Ban Houayxai. Ancillary equipment includes Cat D10T dozers, Cat 16M motor graders and Cat 990 and 992G wheel loaders. PBM also relies on support from Cat dealer Metro Machinery Company Ltd (MMC). The authorised Cat equipment dealer in Thailand since 1977, Metro



Cat also offers Fatigue Risk Assessments including an on-site manager workshop, 90 day intensive data collection, and Fatigue Avoidance Scheduling Tool

Machinery supports PBM operations through its subsidiary Lau Metro.

In 2014, the site management teams, together with organisational support from PanAust, developed a plan to improve the safety performance at its mining operations. The company reviewed four years of safety incident data at the onset of the program in 2014. This initial audit discovered 48 vehicle-to-equipment, or equipment-to-equipment, contact events — an average of 12 incidents every year; plus 38 equipment-to-environment or infrastructure contact events — an average of 9.5 events every year. These 86 events formed the basis for statistical evaluation and were further analysed to determine the primary causes. They found 16 of the 86 events were due to poor communication practices and 26 of the 86 events were directly attributable to fatigue. The remaining 44 events were directly attributable to the procedural and behavioral nonconformance, including 10 events linked to the use of mobile phones while operating machinery.

A basic paper-based fatigue management system was put in place for equipment operators. In addition, operators had been trained and competency records were being kept. The evidence, however, indicated that complacency had set in. Training records were incomplete and trainers had different opinions about what was required. The basic systems were fragmented and didn't communicate with each other. A fatigue management consultant was engaged to review and assess potential risk factors that could arise from the roster arrangements and driving practices on the company's concentrate haul route from Phu Kham to Vietnam. The review included inspections of the route, company-provided accommodation facilities, driver-reviver stops, and a practical assessment of all procedures for managing fatigue.

During the examination of the existing systems, it became apparent that operators failed to understand how their behaviour had directly contributed to safety incidents. Even when investigations showed that an operator was at fault due to fatigue or distraction, the operator was not willing to admit to it. This issue came back to culture. The immediate challenge was to get the workforce to understand that compliance to safety should be of equal concern as retaining employment, ensuring that crews understood their duty of care requirements and would be responsible for championing and owning their workplace safety.

The next step in the safety journey was the introduction of onboard cameras that monitored operators in the cab and provided a live feed to a team responsible for monitoring behaviors and looking for signs of fatigue. With these and the other initiatives in place, PanAust saw a significant improvement in safety statistics. By December 2016, the total recordable injury frequency rate (TRIFR) at Phu Kham had decreased from 5 to 0.5, including 10 months at 0 level. The first aid injury frequency rate dropped from 25 to 4, and total potential lost-time injuries had decreased from 43 to 7 events.

The data showed that progress was being made, but site teams knew more could be done. In late 2016, mine managers from Phu Kham and Ban Houayxai observed Cat DSS at that year's *MINExpo* in Las Vegas. What this system offered PanAust's mines was the ability to immediately notify an operator if they were driving while distracted or drowsy. The system does that by itself, without any input from the operator or someone watching a screen. It also links education with action to encourage fatigue awareness and a change in behaviour. For example, when the DSS detects a second microsleep, the operator is immediately removed from the truck and a fatigue assessment is conducted. During this assessment, the operator has the opportunity to understand the contributors and proxies to fatigue, such as hours of sleep, medication, yawning, dehydration and head nodding.

After the mine managers returned to Laos, safety initiatives continued to be refined and improved on both sites. While some progress had been made, fatigue and distraction continued to be an issue and the fatigue committee continued to search for additional solutions. In 2017, the committee began to evaluate fatigue management technologies and circadian rhythm

monitoring watches for personnel. In 2018, PBM mining installed the DSS on five haul trucks at the Phu Kham operation and implemented a trial of the Cat Smartband. They also partnered with Caterpillar on a Fatigue Risk Assessment, which used data from the DSS and the Smartband to provide real information that would reveal the scale of the problem.

After seeing the results of the trials at Phu Kham, the company made the decision to move forward with DSS system across the entire truck fleet at both operations In 2019, PBM approved the purchase of the DSS, with equipment delivered to the site in July and implementation completed just 66 days later. Unlike the previous in-cab system, the DSS doesn't deliver a live feed that requires someone to be watching the operators at all times. The DSS is not closed-circuit television, and someone is alerted only if there is a fatigue or distraction event detected.

In the first six months after full implementation at Phu Kham to end-December 2019, the mine saw a 41% reduction in overall fatigue events and an 80% reduction in truck operators being required to be relieved from driving due to fatigue. This data indicated that events attributed to fatigue were being reduced, as were the times operators were experiencing fatigue. This points to a successful cultural shift that the site safety team had been seeking. The metric Mean Time Between Sleeps, which measures the average fleet trucks hours against the microsleeps, shows that both sites are continually improving and have not yet plateaued.

Other operations recently deploying Cat fatigue management tech include Glencore's Lomas Bayas copper mine in Chile, which is now using Caterpillar's Smartband to complement the DSS on the haul truck fleet. Head of Dispatch, Percy Sierralta, said the system will help the operator to notify, in advance, the Head of Shift in case of not being in a condition to operate their shift. "Our Superintendents of Mine Operations, in conjunction with our Dispatch and Technology teams, have developed a pilot program with a group of operators in training from the Mujeres a la Carga program. With this Caterpillar technology, in the form of a wristwatch that is equipped with an accelerometer, plus a telephone application, our operators will know how much they slept and what was the quality of their rest. In this way, they will be able to quantitatively determine whether or not they are in a position to operate," explained Sierralta. "I use it as a watch and as a sleep monitor. It is a device that helps us to verify fatigue and drowsiness on the cell phone. In this way, I can keep track and report if I feel fatigued," says Karen Escobar, Mine Equipment Operator.

GCAA has now rolled out Hexagon's HxGN MineProtect Operator Alertness System Heavy Vehicle (OAS-HV) at 11 mines on nearly 500 mining trucks and water trucks

This innovative tool, which is also Smartband's first implementation in Chile, the mine said will provide peace of mind to all its operators, who will be able to achieve a healthy lifestyle without risks, which requires maintaining control and a permanent history of sleep behaviour and hours.

Glencore Coal's fatigue monitoring journey in Australia

A detailed presentation entitled GCAA Operator Alertness System Implementation Project was given in April 2021 by Neil Pollard, Fleet Technology Superintendent for Glencore Coal Assets Australia that summarised GCAA's journey in identifying fatigue as a problem and taking steps to address it through technology introduction. The presentation was given in a webinar organised by the ICMM, as part of its Innovation for Cleaner, Safer Vehicles (ICSV) initiative, which brings together 28 of the world's leading mining and metals companies with the largest OEMs in a non-competitive space, to accelerate the development of a new generation of mining vehicles and improve existing ones.

The initial site-based trial began in 2016 and was an initiative of Ravensworth Open Cut (ROC) due to six fatigue related incidents involving heavy equipment occurring within six months at the mine. Heavy equipment operator fatigue was identified as an area of concern within the company but was unquantifiable, relying on self-reporting and/or operator confession that an incident involved operator impairment/fatigue. Two camera-based technologies (Guardvant MineProtect-OAS and another system) were trialled at ROC back to back over a two-year period. Glendell Open Cut also trialled the Guardvant MineProtect-OAS system during this time. The OAS or Operator Alertness System is a non intrusive eye closure and distraction monitoring solution built for the mining industry with onboard hardware including cabin camera and front facing camera, infrared sensor and in cabin motion alarm and audible device. Based on the information gathered during the Ravensworth Open Cut trial, which provided a better understanding and appreciation of the fatigue risk, the decision to implement the OAS technology across the entire truck fleet was committed to by the GCAA SLT in July 2017 with all systems to be installed by end 2019 – one of the most significant fatigue management system rollouts in mining involving no less than 11 open cut coal mines in Queensland and NSW. Between July 2018 and November 2019, some 448 units had been installed on mining trucks and water trucks. In that period Guardvant was also acquired by **Hexagon** in August 2018, and the system became known as HxGN MineProtect Operator Alertness System Heavy Vehicle (OAS-HV). Glencore Coal says this system was selected based on achieving numerous functional and performance criteria including its ability to accurately and consistently ID eye closure events as determined through the trial as well as eliminating false positives. A light vehicle unit trial was then carried out by GCAA at its Newlands operation in 2019.

The summarised project benefits – it created an environment where fatigue and inattention events for mobile equiment operators are

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detected in real time. It also provided a layered safety solution to ensure the operator fatigue is managed at the critical point of impairment through in cab alarm activation; through third party intervention via positive communications; and by conducting an on shift fitness assessment and long term when repeated events occur in an individual. It developed a safer mining environment through the reduction and near elimination of fatigue related incidents for heavy equipment in open cut environments. It also realised a shift in culture whereby the operator would previously "power through" impairment pre-system to a period where they were relying on the technology (drive to the alarm) to improving their proactive reporting of their fitness for work status. GCAA also developed a procedural avenue for individuals that have multiple reported fatigue events and provides post shift assistance through Health Intervention Plans. Finally, it provided capturing resources for incident investigations (in cab and forward facing cameras).

This major GCAA rollout in Australia for OAS-HV has also led to success at other coal mines in the country. In its recently published 2020 ESG Report, Australian coal mining major Yancoal, majority owned by China's Yanzhou Coal Mining Company, says it undertook several occupational health pilot projects in 2020 across various operations. A key pilot project included the expansion of the use of Hexagon's OAS-HV. Yancoal stated: "OAS-HV is a non-intrusive fatigue and distraction solution that continuously monitors operators to proactively prevent accidents. Although procedures to reduce fatigue risk have previously been in place, OAS-HV enhances the effectiveness of Yancoal's fatigue detection through features including in-cabin alarm and seat vibration that are linked to the system that alert the worker of unsafe events, as well as a review function that allows recorded video footage to be used to educate workers about fatigue and its implications." The miner said broader implementation of this proven pilot project across other Yancoal operations was planned for 2021. Yancoal's surface coal mining operations include Mount Thorley Warkworth, Moolarben, Hunter Valley Operations (HVO), Cameby Downs & Middlemount (50%).

Wenco advancing SmartCap into new markets

Wenco International Mining Systems Ltd in May 2021 announced its purchase of all assets and intellectual property of **SmartCap Technologies**. Based in Brisbane, Australia, SmartCap assesses real-time fatigue levels and monitors for oncoming microsleeps that create safety hazards.
The SmartCap device has over 5,000 users globally in mining, trucking, and other industries. "This purchase is an important step for the continued growth of the SmartCap fatigue technology," said SmartCap CEO Tim Ekert. "We have made significant progress these past eight years and we are proud of every safety incident our technology has prevented. We believe joining Wenco will enable us to grow even further and increase the safety of even more industrial operations."

This acquisition added a strategic, fatigue monitoring capability to Wenco's safety solution portfolio. Safety is of paramount importance at mines and other industrial sites, where operators must perform long hours of repetitive work while paying close attention to their surrounding environment. SmartCap greatly enhances the ability of operators and other workers in proximity to the equipment to remain safe.

"Wenco has long been observing SmartCap's success in enhancing safety for their customers, and we have been in regular discussion on how we can integrate our technologies to provide a comprehensive, next-generation safety solution," said Andrew Pyne, President and CEO of Wenco. "Ultimately, it was decided that bringing our technology, personnel, and business relationships together under Wenco offered the greatest opportunity for us to deliver on our mutual vision for mine safety."

In recent years, Wenco and its parent, Hitachi Construction Machinery (HCM), have invested heavily in solutions to streamline and optimise the end-to-end mining enterprise, with safety as a foundation. SmartCap adds an advanced, fatigue monitoring layer for operator protection to this digital mining initiative. It is intended to be included as part of HCM's Solution Linkage® family, the ICT/IoT solution platform for global mining and construction customers created in response to increased demands for improved safety, life cycle cost, and productivity.

Wenco and SmartCap argue that EEG gives the earliest possible detection of fatigue through the measure of brain activity, eliciting the widest spectrum of data for actionable insights. "Today, there are several ways that mines can go about mitigating there risk of fatigue related incidents, but none are more precise in their identificaton of an operators ability to resist sleep than EEG technologies."

In market developments, iron ore major Fortescue Metals Group recently extended its use of SmartCap and during FY21, 198 units were in operation across FMG's sites. The company added: "Reporting tools that identify team members working additional hours and a process to support Leaders making changes to reduce fatigue risks are also used across our sites. During FY21, we purchased sleep apnoea equipment to allow our Perth and site-based employees and contractors to self-test for sleep apnoea risks. Together with additional support, team members can improve their sleep quality and reduce the fatigue risks associated with obstructive sleep apnoea."

Another operator to rollout SmartCap recently is AngloGold Ashanti's Iduapriem gold mine in Ghana which has eliminated driver fatigue-related incidents using the technology. Iduapriem installed the system on its fleet of 35 Caterpillar 777 mine haul trucks. "We have had fatigue incidents on the mine in the past. We tried some other technology before, and have now moved on to SmartCap" – said Stephen Asante Yamoah, Senior Manager: Mining – AGA Iduapriem Mine. R. Deane Macpherson, Senior Manager Safety, Risk & Training at AGA Continental Africa Region states: "Since the commencing of this trial at the operation...we have had zero injuries or property damage as a result of fatigue related incidents...the technology itself has the ability to give you proactive, predictive data."

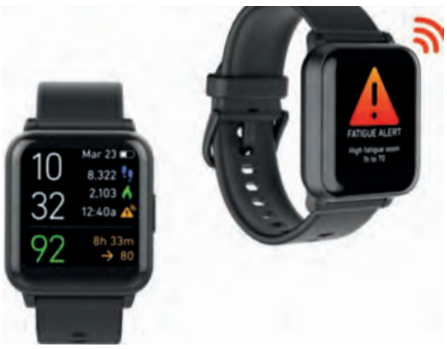
In Chile, BHP has also used SmartCap safety technology devices at Escondida to read brainwaves, identify micro-sleeps, alert operators and identify the hours of greatest risk. Since the program's inception in 2015 up to 2019, 739 employees had been evaluated and 178 had received specialised treatment for associated sleep disorders. These employees now have their fatigue proactively managed so they can safely perform their work. This has led to better safety, health and productivity outcomes at the mine.

Elsewhere, MMG Ltd says the SmartCap technology fatigue management program has yielded positive results at Las Bambas copper mine in Peru which resulted in it being extended to its Dugald River zinc operation in Australia. In the two years since deployment, all SmartCap users on both sites have enjoyed a zero fatigue incident record. The Australian site has adopted an 'every journey, every time' policy with regards to employees use of SmartCap. Wenco states: "As a sophisticated and established SmartCap site, the management engage closely with the SmartCap operations team to test new releases and provide vital feedback."

Anglo American has also deployed SmartCap at several of its operations, including at the Barro Alto nickel operation in Brazil and its Australian metallurgical coal mines including Capcoal.

Fatigue Science introduces ReadiWatch

Fatigue Science recently announced the release of ReadiWatch, a purpose-built smartwatch delivering predictive fatigue awareness and both real-time and predictive Fatigue Alerts to operators and the enterprise in safety-sensitive industrial environments. ReadiWatch expands



ReadiWatch from Fatigue Science is the only wearable that avoids the need for a smartphone altogether

the growing ecosystem of wearables compatible with the Readi Fatigue Management Information System, and FS says it is the first smartwatch designed and purpose-built for industrial fatigue risk management, delivering on a wide array of long-standing customer needs in mining and related sectors.

Offline Fatigue Alerts is foremost among ReadiWatch's industrial features, and the complete experience is on the wrist. "After a single automatic background sync when in proximity of a sync station or smartphone, operators receive both personal sleep insights and a Fatigue Forecast for the upcoming shift. Operators report for duty prepared for the shift ahead with a complete picture of their fatigue risk. ReadiWatch then delivers vibrating wrist alerts when an operator approaches or reaches critical fatigue."

"Delivering simple, actionable fatigue awareness to operators is just one core pillar of a multi-faceted fatigue management strategy. Our industrial customers strongly recognise how a well-managed, data-centric fatigue management system can increase productivity and safety. That's why they rely on Readi's full suite of solutions to engage leadership, operations, supervisors, and operators. ReadiWatch addresses operators directly, providing unrivaled fatigue awareness on a daily basis," says Andrew Morden, President & CEO of Fatigue Science.

Beyond Fatigue Alerts, ReadiWatch is designed to meet the requirements of industrial workflows. ReadiSync, a proprietary passive sync station technology, eliminates the need for operators to pair or sync their device with a smartphone - a critical request from many customers, particularly in the rapidly growing Latin American market. "While Readi supports a wide ecosystem of 3rd party devices, like those from Fitbit and Garmin, ReadiWatch is the only wearable that avoids the need for a smartphone altogether. While smartphone use is also supported, a smartphone-free setup is a real differentiator for many of our customers in Latin America and throughout much of the world," says Robert Higdon, SVP of Product & Marketing at Fatigue Science.

"As with its predecessor, ReadiBand, ReadiWatch offers best-in-class sleep tracking, with 92% validated accuracy as compared to a sleep lab. Additionally, it provides ATM 3.0 water resistance and industrial grade durability, all in a device about 40% lighter than typical consumer smartwatches for maximal comfort during sleeping. With 14-day battery life, roughly three times that of most competitors, it is designed for users to 'wear it and forget it.' Native Spanish support, an array of fitness tracking features, powerful data privacy infrastructure (sleep data remains private), and a more competitive cost than most smartwatches, complete an unrivalled offering for heavy industry."

"We've already seen customers achieve over a 20% reduction in overall fatigue levels by using wearables on the Readi platform, with 80%+ of chronically fatigued operators sustaining improvements over time.

With ReadiWatch, we believe customers will exceed this level of proven performance - a keystone example of using data and technology to enhance productivity and safety in industrial operations," adds Morden.

As stated earlier, Hexagon has now partnered with Fatigue Science, and told ***IM*** on the new development: "Combined with its real-time operator alertness and collision avoidance solutions, Hexagon now helps customers further protect and optimise their people and equipment with a Fatigue Safety Management Platform (FSMP) for predictive fatigue management. The platform not only manages the risks faced by an equipment operator, such as fatigue and distraction, but also covers predictive safety analytics and real-time management. It extends safety from haul truck operators right across the mine site to other operators and employees. FSMP generates fatigue predictions and real-time fatigue assessments based on scientifically validated biomathematical modeling. This makes fatigue quantifiable and thus manageable. Predictive dashboards allow supervisors to plan, intervene and log critical interventions. Combined with change management, education and training, the platform ensures a proven layer of protection against fatigue and distraction, two of the leading causes of accidents in mines."

WOMBATT's voice-based system sees growth

WOMBATT's VOZ is a predictive fatigue prediction technology based on analysis of the voice, using artificial intelligence to analyse multiple voice muscles - accuracy once the algorithm learns the individual's own voice characteristics is up to 90%, higher it says than any other methods available.

Jean S. Verhardt, CEO of **WOMBATT Fatigue Management** told ***IM***: "We have made a lot of progress in 2021, and now have about 1000 users, so moving up the market share rankings. What is very interesting is that one of our most successful applications is North American steel smelting mills, which are similar in environment and operation to mining and mineral processing plants and are highly automated with work being high intensity, difficult and often dangerous. Using mobile phones to make an eight second voice recording three times per shift, we believe WOMBATT-VOZ is the only fatigue technology that is suitable for such a process environment, equally applicable to copper and other smelters. Another new application for fatigue prevention in a mine is with blasting engineers. We have two years of very successful operations with a group of blasting engineers in Peru, who have improved from a Red fatigue alert incidence of about 5% at the start to just over 1% today. Our customers also use the 8 second voice recording as a safety learning opportunity. The mine Standard Operating Procedures (SOPS) should be known by heart by all staff but rarely are. We can vary the eight second message every day with a new eight second summary of an SOP, and over time workers learn all the SOPS with continuous learning."

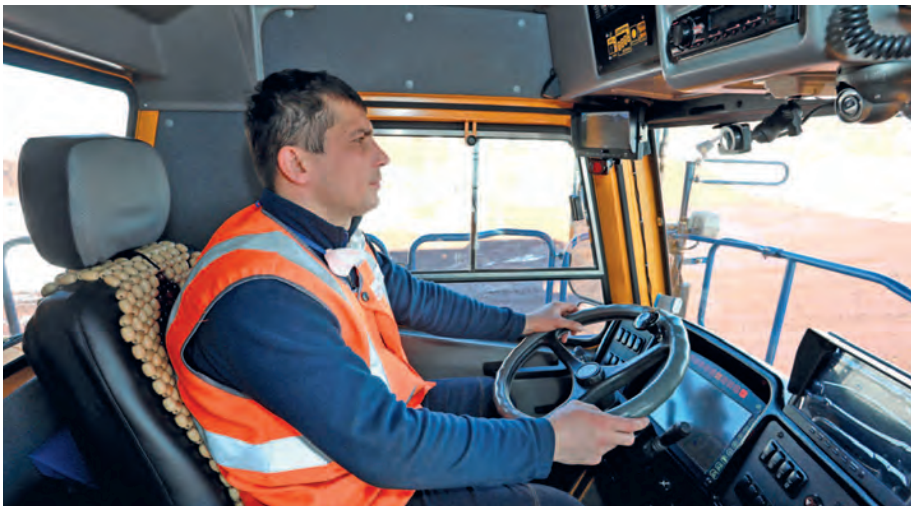
WOMBATT's technology uniquely tracks changes in fatigue through changes in the voice - here operators are receiving training in system use

Verhardt adds that field operations in gold mining in the US have proven that WOMBATT's on-intrusive voice analysis which predicts the risk of fatigue up to five hours ahead, and reduces the incidence of Red alerts by enabling management to take action in time, educates users in the causes of fatigue and sleepiness and reduces the incidence of lack of sleep at home, which is the root cause of fatigue at work.

OKO Mining systems installed in Russia

New 240 t trucks at Metalloinvest's Mikhailovsky GOK iron ore operations in Russia have recently been fitted with a fatigue management system as part a pilot project in real world conditions. Cameras in the driver's cabin record the driver's facial expressions, eye movements and head-turns, and if signs of fatigue or drowsiness are identified, an audible signal is emitted. Based on the results of the pilot, a decision will be made regarding implementing the system on other equipment in the mine. The **OKO Mining** optical fatigue detection system was supplied by Russian technology company OKO Systems and implemented at site by Engineering Company 'Technology of Mining Works' LLC, with whom Mikhailovsky GOK has signed an agreement to conduct trials.

In more detail, optical sensors in the system monitor the driver's face, eyes and the direction of their gaze. If the driver is not looking at the road – the system produces an audio signal; if the sensors do not 'see' the driver's pupils – the system produces an audio signal; and if the driver's gaze does not return to the road for a long time – the system triggers an alarm. The alarm information is stored in the device's database and transmitted to the dispatcher's online office. The Metalloinvest installation follows OKO Mining having been successfully trialled at Kuzbassrazrezugol's coal operations in Siberia. KRU was the first Russian coal company to introduce a fatigue monitoring system to improve industrial safety.



Operator being monitoring by OKO Mining camera based system in 240 t BELAZ truck at Metalloinvest's Mikhailovsky GOK iron ore mine in Russia