Vehicle automation in production environments

by C. Swart*, F. Miller†, P.A. Corbeil†, V. Falmagne‡, and L. St-Arnaud≠

Synopsis

Automation technologies are increasingly adopted in different mines world-wide. This paper presents the technical aspects of vehicle automation applications at two Noranda operating mines.

Teleoperation of 5 LHDs at Noranda's Bell Allard mine is used in order to meet aggressive mining requirements under difficult conditions. The equipment is performing under high demand for reliability and performance. In order to further increase performance, automated loading has been commissioned on one of the LHDs and is being tested. Results to date indicate improved performance with respect to an operator through better filling of the bucket, fewer passes at the muck pile and shorter cycles.

Noranda's Brunswick mine is currently commissioning an automated haulage zone where two optically guided trucks transport ore from a remotely operated chute to two ore passes. Expected operational advantages include increased system capacity and enhanced safety and comfort for the operator. Monitoring to date indicates that the trucks can operate reliably under the conditions imposed by mine production.

Introduction

With low commodity prices, fluctuating demand for metals and international competition, it is well known that mining companies need to be creative in order to be sustainable on global markets. Furthermore, as richer and easily accessible deposits are depleting rapidly, the industry has to move towards orebodies with less favourable geographic, geological, mining and operational conditions. The combined effect of these factors on profitability has driven continuous requirements to reduce production costs. For several years, automation has been considered as a potential solution to improve productivity, equipment utilization, reliability and worker safety (Hurteau *et al.*[1]). Although significant research efforts and technological progress have been done, the success of practical applications is still subject to the challenge of adapting the technologies to the intended operational and human context. Paraszczak and Planeta[2] offered a recent summary of the situation.

This paper presents recent progress in the implementation of vehicle automation through applications at two operating mines. Technical and equipment aspects are mainly discussed here; a parallel paper by Falmagne *et al.*[3] discusses operational conditions, implementation challenges and human factors associated with automation of operating mines.

Teleoperation and automatic loading at Bell Allard

Bell Allard is a recent Noranda underground mining operation located in north-western Québec, Canada. The highgrade zinc orebody lenses are relatively deep (below 1200 metres) and extend east–west on approximately 250 metres. Fast cycling open stoping methods are required to produce 2100 tpd. The typical mining layout (Figure 1) requires the operation to remotely extract more than 85% of the ore.

In such situations, the operator is usually standing and working remotely from a safety platform (Figure 2) located at 10 to 40 m in line-of-sight of the stope corner. However, because of Bell Allard's 'hockey stick' layout, the vehicle is driven at 10 to 25 m deep in the stope at 90 degrees, from the operator, creating a blind mining situation (Figure 3). This situation is well recognized by others in the industry as difficult, stressful, and with limited productivity except for very well trained and experienced operators (Dudley[4]). In order to meet this challenge, Bell Allard chose to use a tele-remote system, which uses an RF communication path to link the operator to the vehicle.

* *Atlas-Copco Wagner*

† *STAS — Mining Division*

‡ *Noranda Inc. Technology Centre*

 SA ISSN 0038–223X/3.00 + 0.00. This paper was first presented at the SAIMM Symposium: Mine Mechanization and Automation *25–28 September 2001*

The specific LHD equipment currently in use are Atlas Copco Wagner ST1010 equipped with SIAM teleremote systems. The system is based on a Device Net Canbus network distributed on the vehicle (Figure 4). The main modules (radio transmitter and dash interface) are located in the middle of the scoop in front of the operator compartment in a protective box bolted to the hydraulic cover panel. Other modules, such as a pulse width modulator (PWM), are installed on the vehicle.

A bi-directional 2.4 GHz digital radio system is used to transfer alarms, operating status and diagnostic messages to the operator unit on a two-line fluorescent display.

Automatic radio digital security technology is used to ensure frequency separation (Miller and Laperrière[5]). Digital video images are transmitted through the same high-speed radio link resulting in high stability, real time and constant images. The video is displayed on a lightweight portable monitor independent of the remote control.

Bell Allard currently uses two cameras, including a mobile one in the front to allow vision adjustment. The system is upgradable to support up to four cameras, including a fast pan and tilt system, if required.

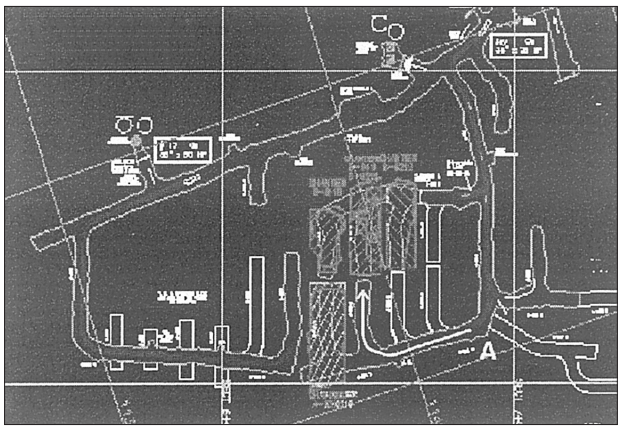

Figure 1—Typical plan section showing the 'hockey stick' layout. Point A shows where the platform is generally located and the arrow represents the work path

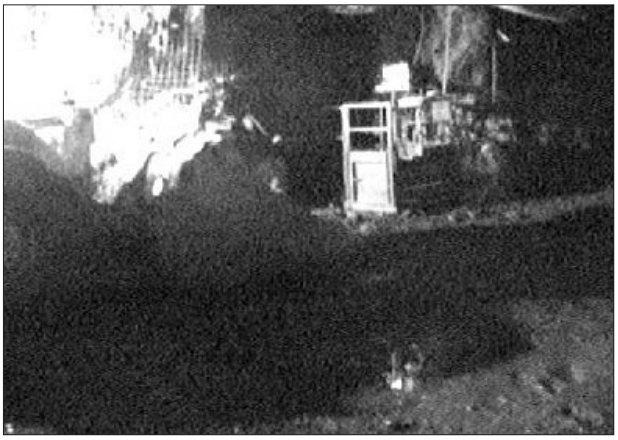

Figure 2—Operator stand located near the main drift

Figure 3—Typical view down the stope at Bell Allard

Automatic loading

Despite the performance of the video remote, difficult operating and mining conditions such as low visibility, difficult roadbeds, fast cycling, small openings, and sharp corners create high demand for equipment manoeuvrability and operator dexterity (Hubert[6]). Operator experience and

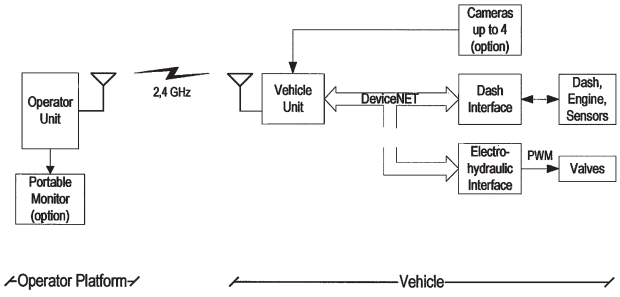

Figure 4—Teleremote block diagram

Figure 5—ST-1000 Teleremote machine with double cameras and autoloading

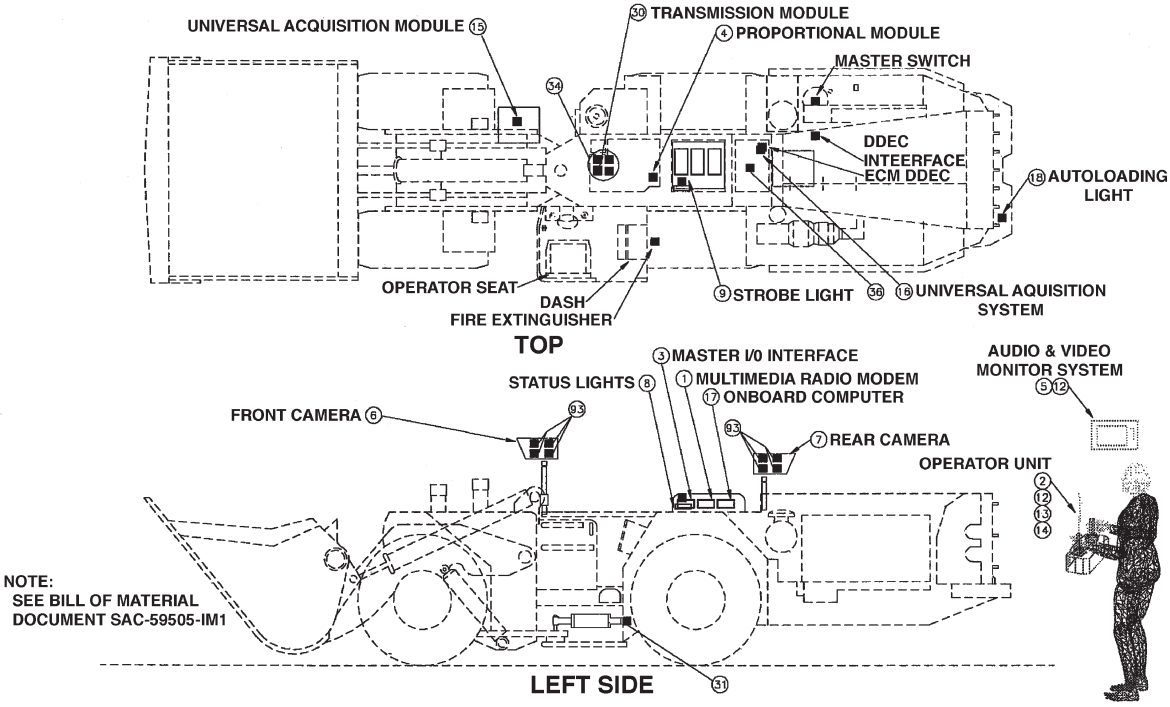

Figure 6—Teleremote and automatic loading system block diagram

patience is especially solicited to fill the bucket rapidly and efficiently and performance can be particularly affected by the skill level of individual operators. With the blind mucking conditions encountered at Bell Allard, automated loading is viewed as a second technological step to improve overall equipment and operation performance. Hence, a SIAMload automated loading system is installed on one of Bell Allard's ST1010 and is operating as part of the production fleet.

The system shares several of the remote control modules such as the Device Net, the radio and the dash interface. Additional components added within the machine network include an on-board computer (OBC), two acquisition modules and a set of sensors (Figure 6). (Laperrière and Miller[7])

The system is based on a direct sensor feedback approach. Similarly to a human operator, autoloading adjusts the vehicle behaviour based on the integration of signals from cylinder extensions, hydraulic pressures and other machine conditions.

The operating approach is based on intrinsic software keeping the machine constantly within a safe operating envelope. These mechanisms allow the system to adapt the loading strategy to muck pile conditions. The system can handle large rock fragments buried inside a pile.

The operator starts the system directly from the remote unit once the vehicle is in front of the muck pile. Three loading styles are available, one for well-fragmented rock, the second for difficult and large pieces of rock and the last one for situations where it is not possible to dig deeply in the muck pile, such as near a wall.

As soon as the system is activated, the scoop bucket is lowered to the proper position automatically or with operator intervention if necessary and the LHD moves forward following ground level. Upon contact with the muck pile, the boom and bucket cylinders are activated to dig into the pile, adopting a penetration strategy based on sensor feedback. Once completed, the machine backs out, shakes the bucket to remove loose pieces, weighs the load and displays the result on the remote control unit. With this type of automation, the operator therefore acts more as a process supervisor than an executor, allowing him to be more attentive to his environment.

The mucking operation results are recorded on an automatic data retrieval system included in the teleremote\automated loading package. Data such as, weight, mucking style and production time, can be recovered and analysed after each shift by downloading on a PC system. The procedure is done through the remote unit safety key.

As observed by other authors and corporations (Paraszczak[2], Puhakka[8]), automation can deliver maximum benefits when several processes are integrated to improve productivity and reduce operating and maintenance costs

Figure 7—Image from the video showing autoloading in action

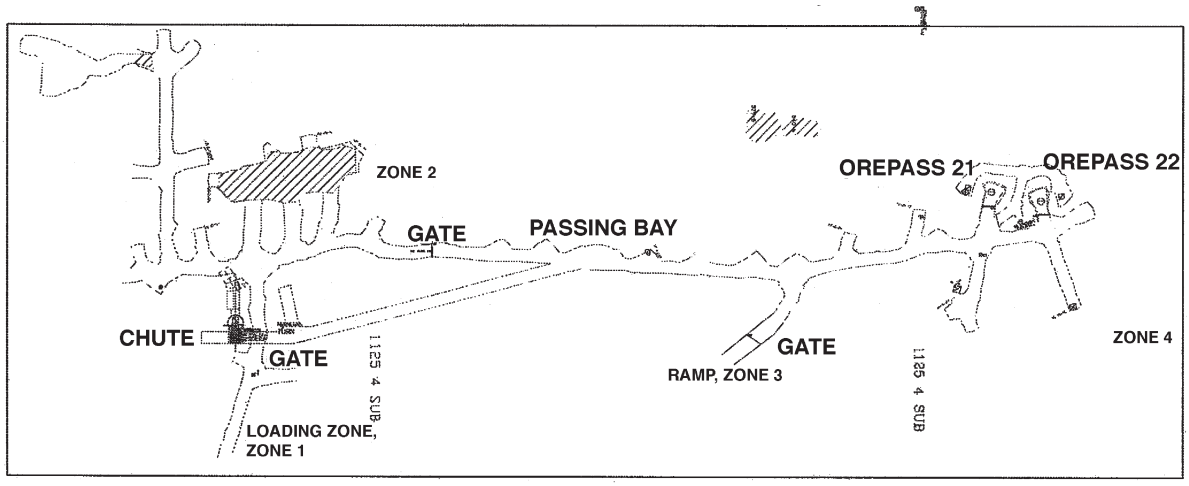

Figure 8—Isolated automated haulage zone

through less overload and machine abuse. These benefits are currently being achieved at Bell Allard and will be the subject of later publications. In addition, two other SIAMload are awaiting commissioning on ST8B vehicles at Brunswick mine.

Automated truck application at Brunswick mines

Located in the eastern Canadian province of New Brunswick, Brunswick mine produces 9400 tpd from a deep massive sulphide deposit which has produced, since 1964, more than 100 Mt. As at any mine, Brunswick is constantly alert to any technology, which may help to improve productivity and reduce costs.

After studying many options, Brunswick decided to install an autoguided truck haulage system on their 1125 level (Figure 8). The trucks are used to transfer material from 23 ore pass (left side) to ore passes 21 and 22 (right side). More details on production configuration and operational benefits are available in the paper by Falmagne *et al.*[3].

In order to maximize safety and productivity during and between shifts, the 400 m haulage area is physically isolated and dedicated to the system. The area is used simultaneously by two autonomous Wagner Atlas-Copco 436B trucks, with a third instrumented truck available as a spare.

The automatic system consists of three main components (Figure 9): a communication backbone, a zone management system and the autonomous guidance system itself. The communication infrastructure consists of a standard CATV cable supporting a bi-directional and high speed distributed antenna system for real time data exchange between the vehicles and the management system. The backbone is laid out along the haulage zone and transmits the supervising information for the guiding system and the analogue camera signals from the video network to monitor the vehicles all along the haulage circuit.

All the information is brought to the communication head-end located in the control room near the loading chute. In addition to the communication system, a dedicated PLC DH+ (Data Highway Plus) network is installed along the haulage area to transport drift instrumentation information to the master traffic PLC controller system responsible for controlling zone access, opening or closing vent doors, and confirming truck localization. Drift instrumentation consists of PLCs and different sensors localized at the access gates, ventilation ore pass doors and along the isolated zone.

A PLC SCADA system (Figures 10 and 11) manages the entire operator interface for starting, stopping, and supervising the guided vehicles and the surrounding systems. The operator can verify vehicle locations in real-time using a multi-video screen, as shown on Figure 12. All

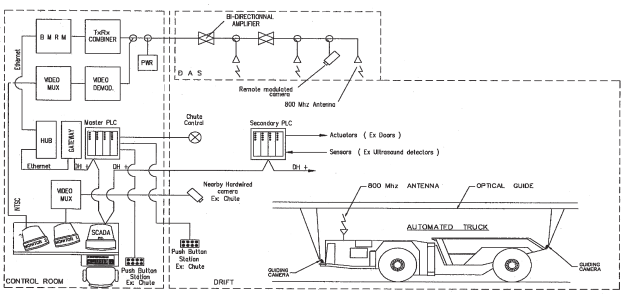

Figure 9—Automated guiding system block diagram

Figure 10—General view of the control room located near the loading chute

the safety aspects, such as interlock procedures, are controlled by the master PLC in the control room. As the vehicles travel along the drift, the automated guidance system can send and receive information from the master systems and be interrupted at any time. To achieve efficient traffic management, a set of strict rules have been implemented in the PLCs, taking into account safety, productivity and cycle optimization

At each cycle, the master system monitors and decides vehicle movements, waiting periods and dumping operations.

The vehicle guiding system shares the same vehicle Device Net infrastructure described in the previous section. Extra sensors are added to provide supplemental data (Figure 13). For the implemented system at Brunswick, the guidance system itself is based on a vision navigation technique. An on-board computer, similar to the one used on autoloading, analyses images and decide appropriate driving actions.

Two cameras, one for each direction are used to get images from the roof optical reflective tape. The rear camera is well protected by a retractable housing (Figure 14). If necessary, the system can switch to odometric guidance and can execute movements that have been stored in memory during a set-up period.

The autonomous vehicle can change gears and direction along the path depending on the configuration of the cycle. The vehicle can go as fast in reverse as in forward and has reached 3rd gear half throttle the maximum practical speed on the short level section of the haulage drift.

The automated haulage cycle starts when all the systems, including vehicles, have been verified. The trucks are then localized in the drift and identified within the starting SCADA screen procedure followed by the tramming supervisor. All doors must be locked and secure before the trucks are started.

The cycle begins with a first vehicle localized at the loading chute in order to be remotely loaded by the control room operator. As soon as the first truck leaves the chute (Figure 15) and passes the top part of the ramp (Figure 16), the second vehicle comes in reverse, down the ramp, and to the chute to be loaded. A few seconds only are necessary to load the trucks. When ready, the second vehicle leaves the chute to climb the ramp and travel up to the dedicated ore pass. Simultaneously, the first vehicle will dump automatically at the ore pass and start the return trip for the next cycle.

All vehicle movements are constantly monitored by all systems to prevent any errors. On errors, a message can be sent from any system on the network, analysed, and an alarm is displayed on the supervision screen. Depending on the severity of the message, the system will continue or stop.

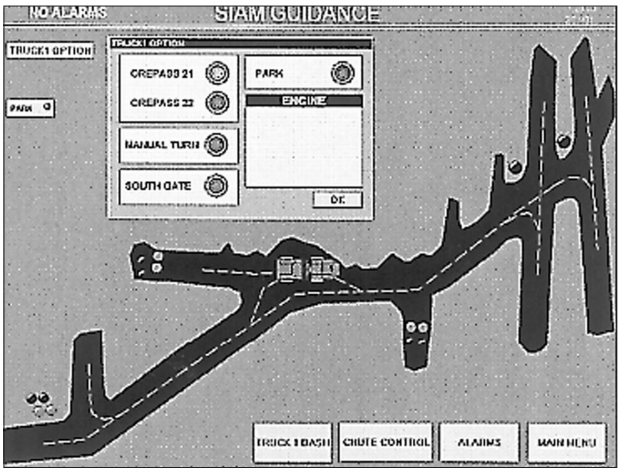

Figure 11—View of one of the SCADA screens used for guiding and traffic control system

Figure 12—Nine screens split-up showing real time information during guidance

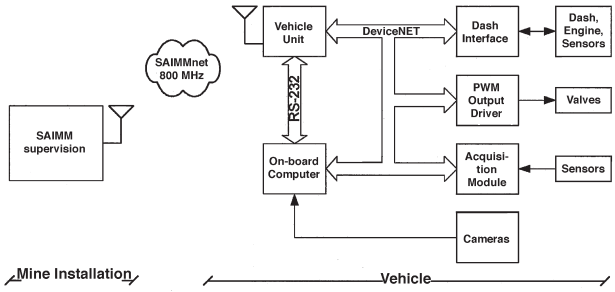

Figure 13—Vehicle interface

Figure 14—Protective housing for the back camera

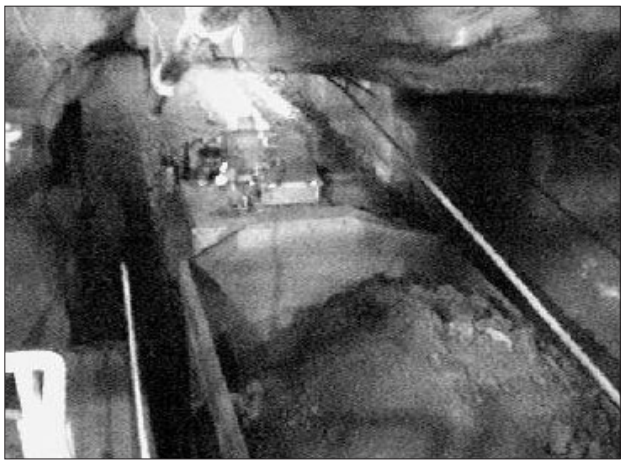

Figure 15—Picture extracted from the video monitoring system showing a loaded truck leaving the chute

Figure 16—Picture showing two trucks leaving the passing bay, one in the direction of the 21 ore pass and the second going back to the loading chute

All status and alarms are recorded. A diagnostic system, and telephone and on-line services are also available for the operator.

The current results at Brunswick are very encouraging and indicate that the system is responding as planned. The total cycle (2 vehicles loading, tramming, dumping and return) currently takes between 9 to 12 minutes, depending on the loading process. The first step of the project has been successfully implemented and production results are monitored carefully. Further improvements are expected this fall and production data should soon be available for future publication. Provision has been made for future operation of the system from surface.

Conclusions

This paper has presented applications of three automation technologies at different production or pre-production stages. These applications demonstrate that automation systems can help mining operations enhance productivity under difficult conditions.

Automation technology applications will continue to evolve. For example, with the appropriate communication backbone, tele-remote, autoloading and guidance systems will be used directly from a control room located anywhere underground, on surface or from a distant location. In the near future, the implementation of automation projects will be facilitated, as automation-ready options will become available from vehicle manufacturers and with the increased availability of suppliers capable of manufacturing and support.

Acknowledgements

The authors would like to thank the Brunswick and Matagami Divisions of Noranda for permission to present this paper as well as for their contribution to the projects. Efforts of the technical and project team at STAS-Mining Division are especially acknowledged.

References

1. Hurteau, R., Piché, A., and Dubé, P.B. Vision and guidance systems—a new avenue for mining. *Proceedings of the Second International Conference on Innovative Mining Systems,* Penn State University. 1986.
2. Paraszczak, J. and Planeta, S. Man-less underground mining-hurdles on the way to make dreams come true, *CIM Annual General Meeting,* Québec City, Canada. May, 2001.
3. Falmagne, V., Moerman, A. and Verreault, M. Beyond development; Challenge and benefits of implementing automation technologies in Noranda's mining operations, *6th ISMMA—nternational Symposium on Mine Mechanization and Automation,* Johannesburg, South Africa. September 24-27, 2001.
4. Dudley, J. and Scott F. Tele-Remote LHD Implementation & the Progression to LHD Automation at Northparkes E26 Block Cave Mine, Northparkes Mines, Australia, *TELEMIN conference,* Sudbury, Canada, 1999.
5. Miller, F. and Laperrière, Y. SIAM: An Integrated Automation System for Underground Mining, *CIM Annual General Meeting,* Montréal, Canada. May, 1998.
6. Hubert, G. Tele-operation at Freeport to Reduce Wet Muck Hazards, *MassMin 2000.* Brisbane, Qld, Australia. 29 October-2 November, 2000.
7. Laperrière, Y. and Miller, F. Automatic loading of LHDs, *5th International Symposium on Mine Mechanization and Automation.* Sudbury, Canada. June 14-16, 1999.
8. Puhakka, T. Optimising Mobile Equipment Resources in Massive Mining, *MassMin 2000.* Brisbane, Qld, Australia. 29 October-2 November, 2000.