# Mine Mechanization and Automation at CANMET, Natural Resources Canada

by M. Laflamme*, M. Bétournay* and A. Miller†


## Synopsis

**The main objectives of the Mine Mechanisation and Automation program (MMAP) are to enhance health and safety in underground mining operations, facilitate mechanization and automation in narrow-vein and deep mines, provide sound science to regulatory agencies and improve mine profitability.**

**The program, which has a unique underground and surface industrial scale facility, is involved in many multi-partner projects, like hydrogen fuelcell applications, electrification and hydraulification of underground mines, reduction of noise and vibration, miner location device, explosive-free blasting and hoisting.**

**The paper presents an overview of the Mine Mechanisation and Automation Program of Natural Resources Canada and some of the main projects.**


## Introduction

Natural Resources Canada (NRCan) is a federal government department specializing in the sustainable development and use of natural resources—energy, minerals and metals, forests—and in Earth sciences. NRCan deals with natural resource issues that are important to Canadians. These issues are examined from both a national and international perspective, our expertise in science and technology, policy and research programmes. How we manage our land and resources today will determine the quality of life for Canadians now and in the future. The activities of NRCan in the mineral resources are realised within the Mining and Mineral Sciences Laboratories (MMSL) of CANMET, which include the Mine Mechanisation and Automation Program (MMAP).

Based at the Experimental Mine in Val d'Or, the MMAP has for its goal to enhance health and safety in underground mining operations, facilitate mechanization and automation in narrow veins and deep mines, provide sound science to regulatory agencies and improve mine profitability. The MMAP is involved in a number of major projects such as the application of hydrogen fuelcell in underground mining equipment, electrification and (water powering) hydraulification of narrow vein mines, reduction of noise and vibration, miner location device, and hoisting.

## Mining and Mineral Sciences Laboratories

MMSL's mandate is to provide quality research and development services, technology, and sound scientific advice to:

- Canada's mining, mineral and related supply industries
- Provincial and federal government departments involved in promoting or regulating the industry.

MMSL's list of clients include:

- The federal government, in support of policy development and in such issues as promoting and defending trade
- The primary mining and metals producers and processors in Canada
- The wider 'cluster industry' market of consulting engineers, equipment manufacturers, and associated environmental and other supply industries
- Provincial government's natural resource and labour ministries.

Figure 1 shows the MMSL organization chart which regroups three main laboratories and a service unit: environment laboratory, process laboratory, mining laboratory and the analysis services.

In particular, the mining laboratories are composed of three research and development programs;

- Ground control program
- Underground mine environment program
- Mine mechanization and automation program.


* *Natural Resources Canada, CANMET, Experimental Mine, Val-d'Or, Canada*

† *Fuelcell Propulsion Institute, Denver, USA*


 *This paper was first presented at the SAIMM Symposium:* Mine Mechanization and Automation *25–28 September 2001*

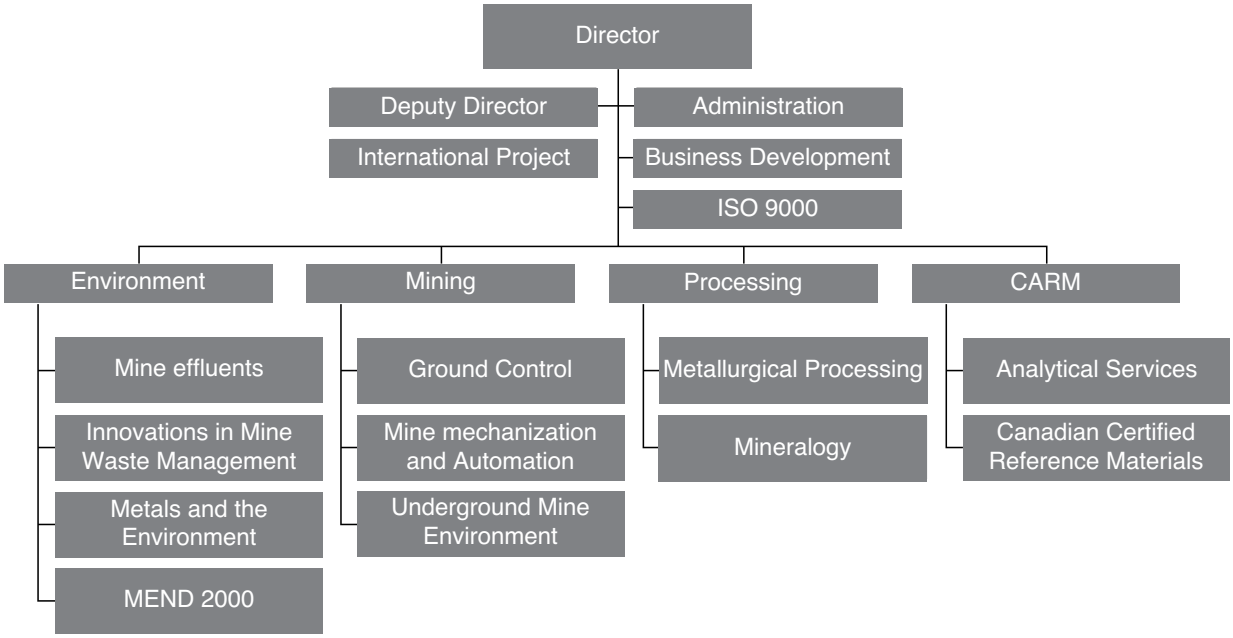


**Figure 1—MMSL organization chart**

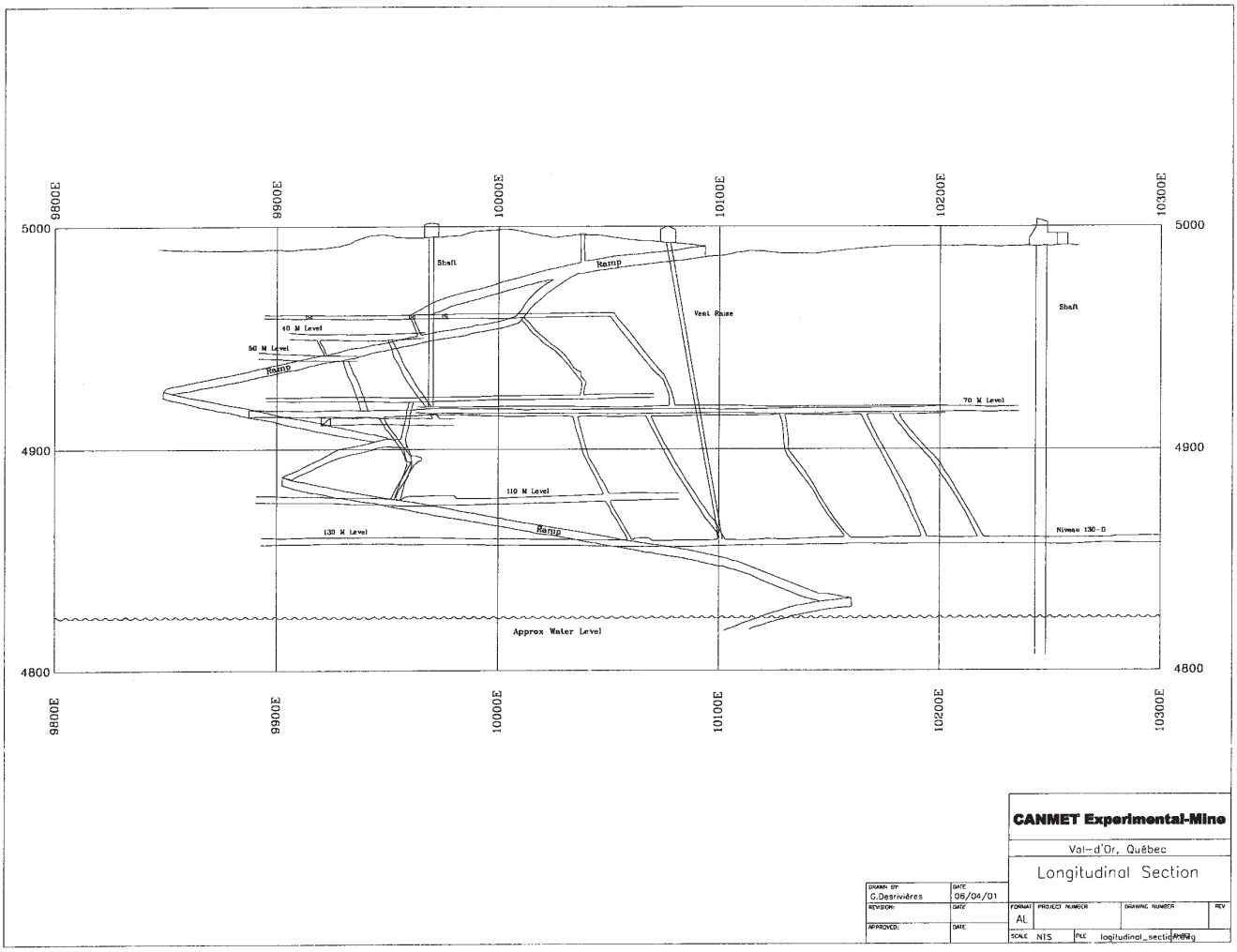


**Figure 2—Longitudinal section – Experimental Mine**

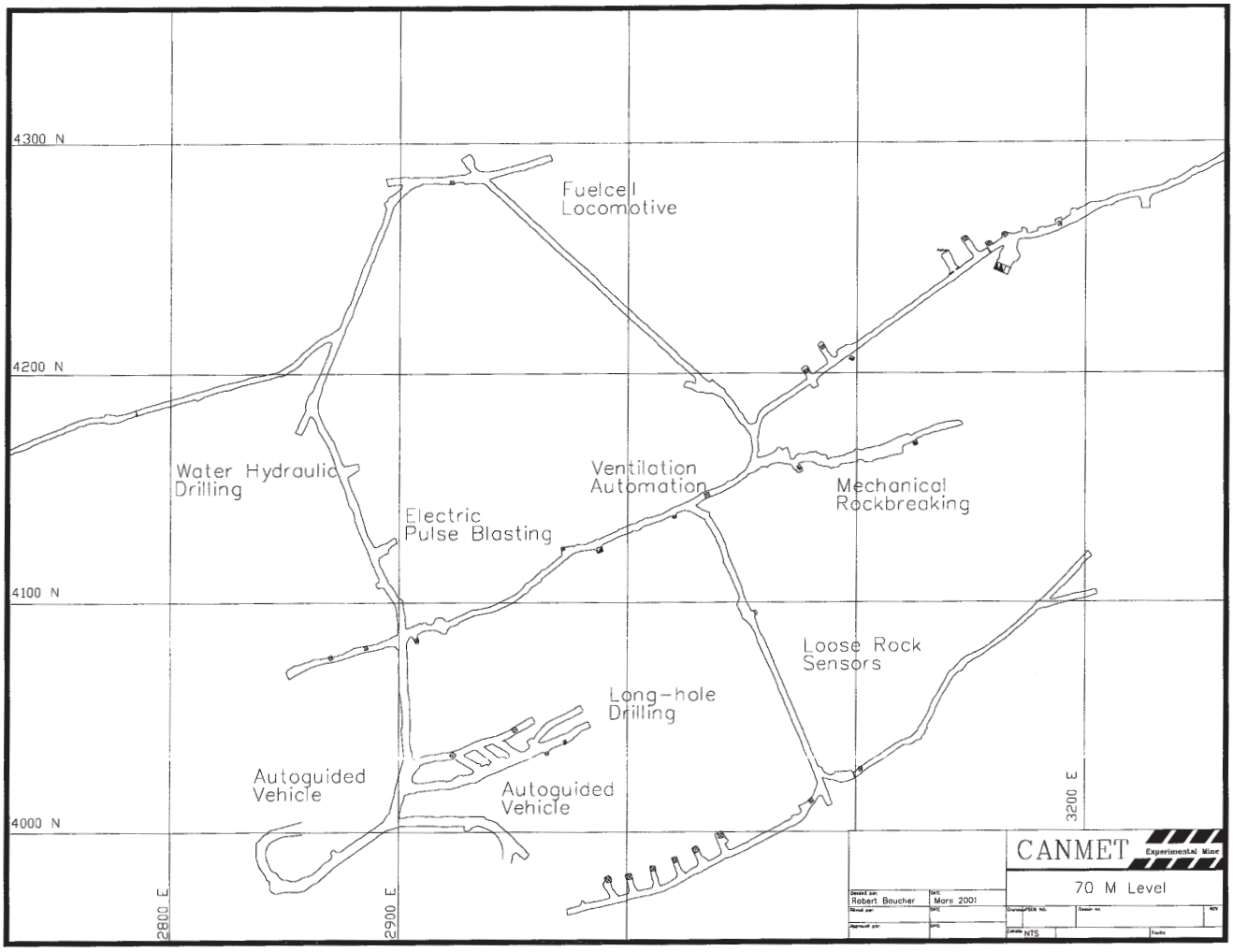


**Figure 3—Experimental Mine—70 metre level**

The activities of these three programs are based in different localities: Sudbury (Ontario), Bells Corners (Ottawa, Ontario) and Val d'Or (Québec). The mechanization and automation program based at the Experimental Mine in Val d'Or relies on unique industrial installations underground as well as on the surface, accessible to the mining and manufacturing industries in order to do research and development work without production constraint.

### Experimental Mine facilities

In 1991, the Department of Natural Resources Canada acquired an experimental mine in order to comply to the needs of the Canadian mining industry and to give more importance to applied research. The installations are located on the site of an old gold mine. The mine was renovated to permit the use of recent technologies and related material.

The Experimental Mine, unique mining site and representative of real operations, presents the following characteristics (see Figures 2 and 3):

- a testing site in hard rock equipped with an access ramp
- five underground levels, including more than 2000 metres of drift, raises, secondary access and extraction stopes
- mining equipment and accessories
- communication and information transmission systems to assure continuous surveillance of the activities
- surface installations, including offices, laboratories and workshop.

### Mine Mechanisation and Automation Program

#### *Main objectives*

The MMAP has three objectives through its activities.

- Enhance health and safety in underground mining operations.
- Facilitate mechanization and automation to improve mine profitability.
- Provide sound science to regulatory agencies.

These main objectives are met through two main thrusts.

- An ongoing effort to develop and improve underground mine equipment and systems, including worker protection and safety devices, as well as alternative mining methods and systems.
- A longer term thrust related to mine automation and alternative to explosives to break hard rock.

The achievement of those objectives is done through a number of projects realised in collaboration with the mining industry, manufacturers of mining equipment, regulation organizations, colleges, universities, as well as federal and provincial governments and this, on national and international levels.

### *Project highlights*

Many major projects are actually being realised through the MMAP. Some are presented hereafter in order to present an insight of the programs' orientations.

#### *Fuelcell locomotive project*

An initiative, co-sponsored by the Fuelcell Propulsion Institute (FPI) and CANMET, has for its objective to prove the concept of safe hydrogen fuelcell application in underground mining vehicles. This would address three important constraints, the new regulation on the permitted level of diesel emissions, the low cost of metals (which is forcing a major reduction in production costs, achievable through the ventilation reduction and productivity increase afforded by the application of fuelcells), and the reduction of greenhouse gases (1Mt of $CO_2$ is emitted every year by underground diesel mining vehicles).

The hydrogen fuelcell locomotive project, one of seven technology introduction projects which includes also the conventional underground LHD vehicle, regroups more than 20 international partners from the mining industry. The mine production locomotive is the world's first fuelcell industrial vehicle.

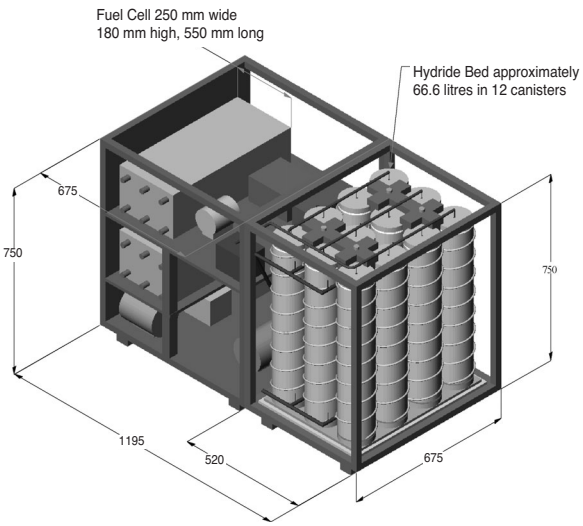


**Figure 4—Fuelcell powerplant**

*Table I*

**Battery and powerplant characteristics**

| Parameters | Battery | Powerplant |
|---|---|---|
| Power ( continuous) | 7.1 Kilowatt (net) | 14 Kilowatt |
| Current (continuous) | 76 A | 135 A |
| Voltage (at continuous rating) | 94 Volts (est.) | 104 V (… stack) |
| Weight of component | 1650 Kilogram | < 550 Kg |
| Volume of component | 520 l | < 250 l |
| Energy capacity (electrical) | 43 kWh | 48 kWh |
| Operating time | 6 hours (available) | 8 hours |
| Recharge time | 8 hours | 1/2 hour (expected) |

The locomotive's fuelcell system uses a proton-exchange membrane (PEM) fuelcells and no electrical battery. The stack is a rugged industrial design, using metal bipolar plates. The power plant for the locomotive is composed of two stacks in electrical series, the hybrid hydrogen storage bed (Figure 4) and system control.

Characteristics of the fuelcell power plant are presented in Table I, in comparison with the locomotive lead-acid battery.

The hybrid storage system, developed by Sandia/California, will store 3 kilograms (kg) of hydrogen, sufficient for eight hours of locomotive operation at the 6 kilowatt (kW) average power of its duty cycle. The bed uses approximately 200 kg of C-15 alloy (manganese, titanium, zirconium, iron, and other constituents) stored in 12 cylinders. The system design allows for rapid change-out (swapping) of a discharged bed with a freshly charged unit.

The evaluation of the locomotive will be done on two levels,

- safety of different components
- performance and reliability of the system.

The first evaluation will be under the responsibility of the Mine Safety and Health Administration (MSHA), an agency with the US Department of Labor. Surface tests will be carried out prior to the underground performance testing. These will serve to validate operational safety of different system components.

The second evaluation will be under CANMET's responsibility. It will serve to measure, on a comparative basis, a number of operational parameters as:

- Tractive effort
- Grade climbing
- Tram speed
- Operating duration on a full charge
- Refuelling time
- Shock and vibration resistance
- Overload capacity
- Ergonomics and human control characteristics
- Productivity
- Reliability
- Availability.

These tests will be done in four underground mines, including CANMET's Experimental Mine in Val d'Or.

#### *Shaft sinking: Human presence detection on the rim of the sinking bucket*

When sinking a shaft for an underground mine, the workers access their workplace using a sinking bucket connected to the hoist by a cable.

According to the Province of Québec (Canada) regulations, when people are transported in a sinking shaft, they must stand inside the sinking bucket. However, it frequently happens that some people stand on the rim as opposed to inside the bucket. In this position, there is a risk of a fall, generally fatal, if for any reason the bucket is destabilized while moving in the shaft. Following a number of these types of accidents in recent years, the Commission de la Santé et de la Sécurité du Travail du Québec (CSST), Québec's Safety and Health Administration, the engineering firm Léandre Gervais and Associates, as well as the Québec government, mandated CANMET so that a solution could be

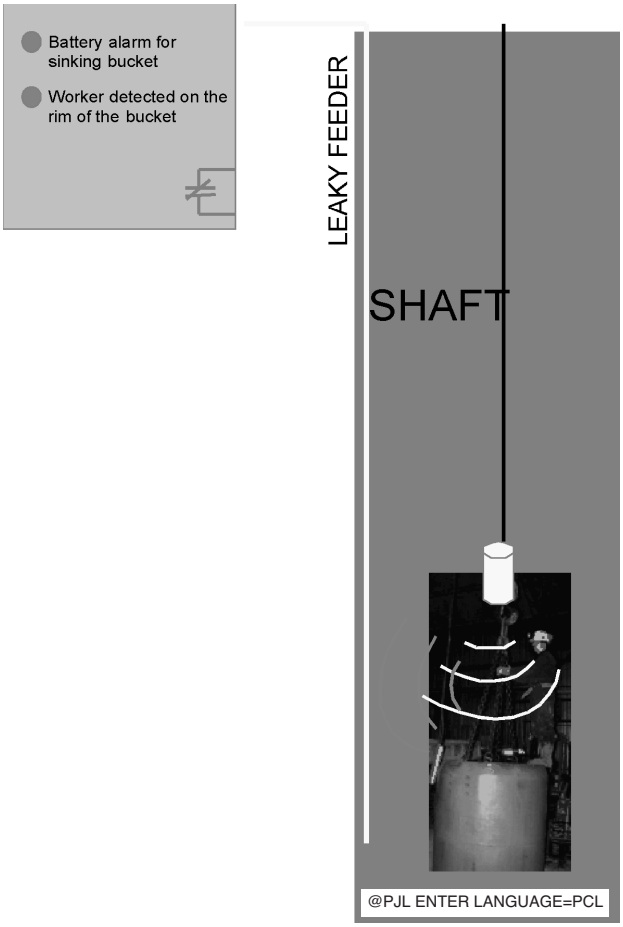


**Figure 5—Shaft sinking — human presence detection**

found. By detecting a presence on the rim of the sinking bucket, and immediately taking action, risks of accidents can be avoided.

The objective of the project was to conceive and fabricate a system capable of detecting any presence of people standing on the rim of the sinking bucket when moving upwards or downwards. If anyone is detected, the information would immediately be transmitted to the hoist room where the action would be taken without delay. For this, three modules are required; a module on the sinking bucket, a module on the miner's battery, and another in the hoist room (Figure 5).

The module on the sinking bucket is made of a treatment bloc used to activate and deactivate an oscillator. The signal is amplified and transmitted in the air using a coil serving as an antenna.

This is energized by a high capacity battery. The microprocessor controlling the oscillator was programmed to optimize the battery life (6 to 12 months depending on the number of batteries used). This transmitter sends electromagnetic impulses in the air in the shape of a cone covering the entire bucket (Figure 6). An internal circuit in the transmitter verifies that the module sent its signal, if not, issues a signal directly to the hoist operator through the communication system in place.

The module on the miner's battery is a receptor fitted with a coil serving as an antenna. This antenna senses a signal from the transmitter on the bucket, filters the information, and measures the intensity with great precision. The closest the worker is to the transmitter on the bucket, the higher the signal will be. If the worker is detected as being on the rim of the bucket, the battery module sends an alarm in UHF signal using its miniature transmitter. This signal is sent on the communication system to the hoist room.

The module in the hoist room receives the alarm signal from the miner's battery module via the mine's communication system. The signal is then decoded and its validity is verified. If the signal is valid, an alarm is posted and the hoist operator must immediately stop the bucket. There are possibilities that this process is done automatically without the intervention of the operator. More/over, all the incidences of alarms are stored for future reference.

The miniaturized concept, which was the focus of intensive testing in shaft sinking at the Mouska Mine (Cambior), will be commercialized for use in future shaft sinking projects.

### *Hoists — PLC booklet*

In the Province of Québec, a guide is available, written in 1993, on extraction machines that rely on the regulation of health and safety in the mines in Québec. This guide presents different safety mechanisms and provides necessary indications to assure the appropriate working order of the machines. With the rapid evolution of technology and the research for profitability in investments, the Programmable Electronic System (PES) are implanted progressively in the industries. The mining sector follows this trend and most mining companies equip their extraction machinery with the programmable command system. However, the introduction of these new technologies, required for the improvement of productivity, must not contribute to an increase in risks.

Through the terminology of PES, are grouped many programmable electronic technologies (PE) based on computer processing, able to understand material, software, and input and output units. These terminologies cover the micro-electric units based on one or many Central Processing Units (CPU) associated to memories and more. The following features are examples of PES:

- Microprocessors
- Micro-controllers

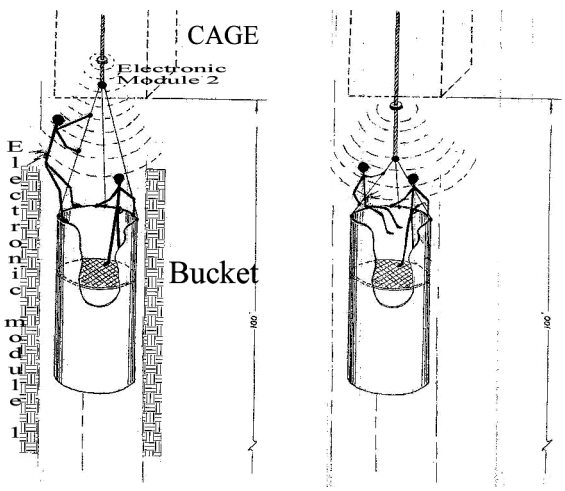


**Figure 6—Shaft sinking — modules of the safety device**

- Applied Specific Integrated Circuit (ASIC)
- Programmable Controller (PC) or Programmable Logic Controller (PLC)
- Other units based on computer technology (for example, intelligent sensors, transmitters, actuator, variable speed drive, cycloconverter, etc.).

The PES are themselves defined as command, protection or surveillance systems based on one or many electronic programmable units. This term covers all the elements of the system, as power source, sensors, as well as other input or output units and other communication networks.

From a safety standpoint, the programmable controllers present three main characteristics of reliability different to those of automatism, based on electromechanical technologies, used previously.

- Failure mode of programmable controllers are not well known and its behaviour on internal default is unpredictable.
- The influence of electrical and electromagnetic interference may be extremely disturbing (particularly from radio communication systems used in mines).
- The possibility of rapid modifications of programs may become an additional source of risk.

According to the National Institute for Scientific Research (NISR), following the state of knowledge, it is recommended to follow these rules:

- The direct safety functions must not be taken uniquely in account of the PC. Even if the safety information (emergency stop, protectors) may be information programmed in the controller. In other words, the direct security must not rest on the good performance expected from the PC.
- If it is absolutely necessary to use the controllers to assure the direct security, specific solutions will have to be taken (dynamism, doubling of the controllers). The level of security will have to be as high as in positive security wired logic. Particularly in the occurrence of failure, it must not create a situation of risk. In a case which doubling the controllers was chosen, extensive elimination of common modes of failure affecting both chains must be made.
- The indirect security functions (auto-surveillance

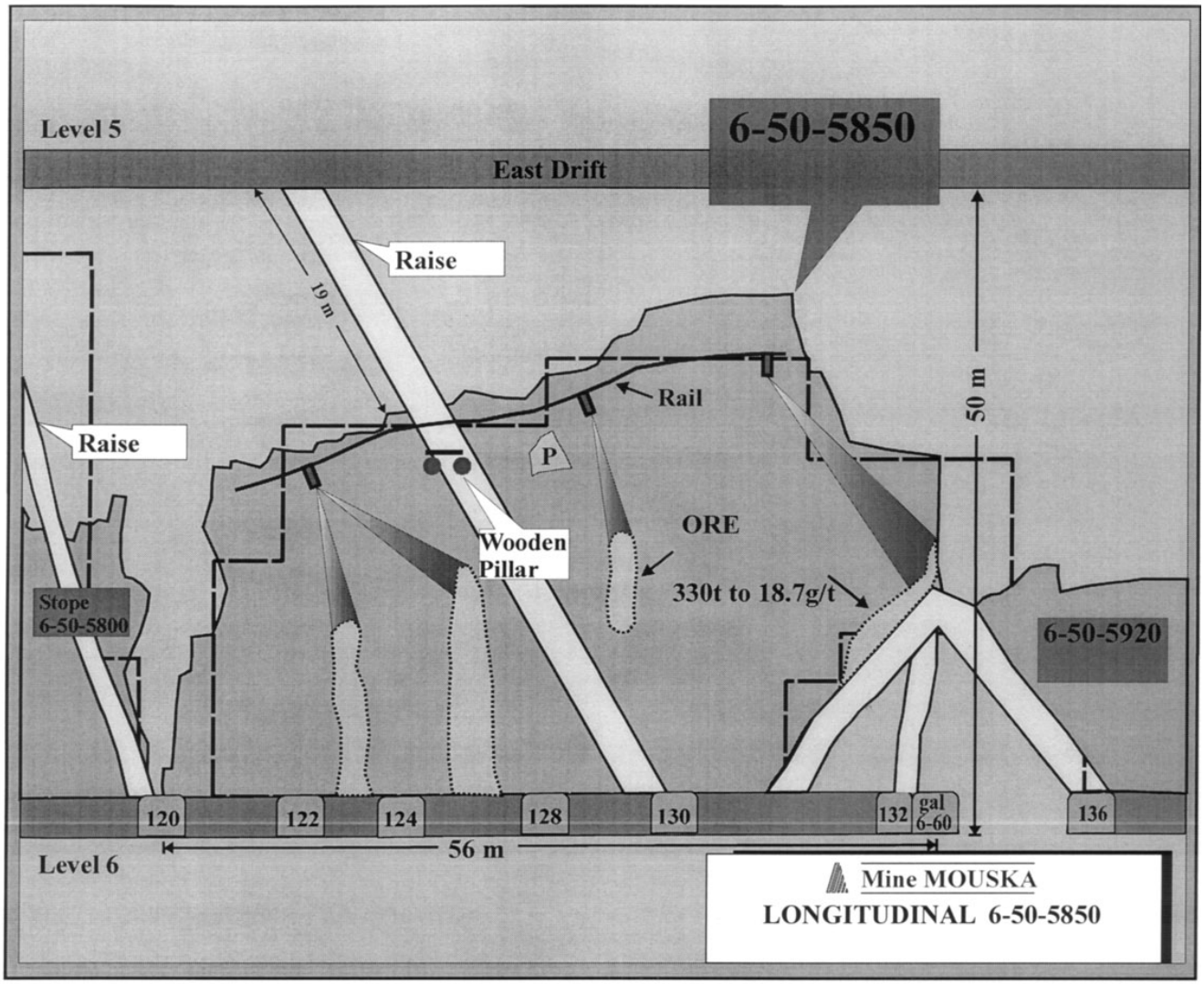


**Figure 7—Shrinkage stope — broken ore pillar**

functions, synchronism, controls) may be assured indifferently by wired logic or programmed logic using the basic rules of the matter.

On the basis of these problems, a joint project between CANMET and the Institut de Recherche en Santé et en Sécurité du Travail du Québec (IRSST), Québec's research institute for health and safety at work, was introduced to issue documentation on the command and supervision systems requiring programmable technologies.

The approach leading to the publication of a pamphlet was based on an informal analysis of risks. It was elaborated with experience, as much that of the manufacturers as of the mine inspectors, and led to prescribing a certain number of solutions. The preparation of the fascicle, based on a non-formal analysis approach, was expanded to the command and supervision systems of extraction machinery using programmable technology.

It is directed to users and installers of extraction machinery commanded by computers. It gives complementary information on attainable objectives in terms of hoist security systems commanded by PES.

The recommendations of the publication mostly concern the general structure of the command and supervision system of extraction machinery commanded by computers, on these particular elements and on the regular testing and verifications. The application of the information should assure that the actual level of safety of the extraction machinery is maintained when the machines are controlled by computers.

### *Tele-operated water jetting gun*

Exploitation by shrinkage stope method presents a certain number of problems, one of which is related to the complete recovery of the broken ore during the final drawing of the ore in the stope. During this operation, approximately 10 to 15% of the ore cannot be recovered because of the formation of ore rubble pillars (Figure 7) which are caused by:

- Particle size distribution of the broken ore kept in place by a high degree of compression
- An oxidation process that bounded the ore
- The plastic deformation of the walls
- Hang-up of the ore on rock or wood pillars left in place as ground support.

Different alternatives were evaluated to assure the recovery of these ore pillars. For effectiveness and security reasons, the chosen alternative was the design and development of a tele-operated watering system.

The module developed, is operated from a superior level, using four electric 24-volt motors to assure its mobility on wooden rail, built in the upper part of the stope prior to drawing (Photo 1). The watering system is activated in elevation and azimuth by two electric motors. As for the vision of the operator, it is assured with the use of a high-resolution video camera and a 50 watt lighting system

**Photograph 1—Tele-operated water jetting gun**

**Photograph 2—Tele-operated water jetting gun**

*Table II*

**Tele-operated water jetting gun - benefits**

| | Total unit cost ($/ton) | Marginal drawing cost ($/ton) |
|---|---|---|
| Definition | 1.33 | 0 |
| Development | 8.77 | 0 |
| Extraction | 35.93 | 8.00 |
| Services | 41.13 | 2.00 |
| Administration | 14.89 | 0 |
| **Sub-total** | **102.05** | |
| Transportation | 8.22 | 8.22 |
| Processing | 27.59 | 27.59 |
| Royalties | 4.81 | 4.81 |
| Immobilization | 15.94 | 0 |
| **Grand total** | **158.61** | 50.62 |
| Ore value | 181.84 | 181.84 |
| **Benefit ($/ton)** | **23.23** | **131.22** |

mounted on the watering system (Photo 2).

Testing at Cambior's Mouska Mine showed important advantages of the system:

- Recovery of 100% of the broken ore
- No secondary blast
- No human presence within the stope
- Good view of the arrival point of the jet of water
- Watering capacity at 90 degrees.

From an economical standpoint, Table II shows the advantages related to the use of the system. Each additional ton drawn returns an additional $131.22. Considering a stope with 15 000 tons of ore, of which 10% would be lost in the pillars, or 1500 tons, the economical impact of such a system is nearly $200 000 for a single stope.

### Future challenges

The Mine Mechanisation and Automation Program at CANMET is implicated within many other projects, as the underground vehicle tracking system, communication in a noisy environment, vibration reduction, hydraulification of underground mines (Candrill Rockdrill), underground vision in situations of tele-operation and more.

The field of mine mechanization and automation faces many challenges: new safe sources of energy for underground mines, rock breakage without explosives, optimization of tele-operations, standardized communication systems, deep mining and mining in the north.

### References


1. FORTIN, G. and DEMERS, R. Les machines d'extraction, Guide, *Commission de la Santé et de la Sécurité du Travail du Québec*, 1993.
2. VAUTRIN, J-P., DEI SVALDI, D., Les automates programmable: Nouvelles technologies, nouveaux risques, principes de sécurité à appliquer, *Institut National de Recherche en Sécurité*, Cahiers de Notes documentaire, ND 117, 1984.
3. MILLER, A.R., BURSEY, H.A., STORY, G. COOK, BÉTOURNAY, M.C., THOMAS, G.J. Underground Fuelcell Locomotives and their Applications; Proceedings Fuelcell 2000 Conference, Lucerne; (in print). ◆