Development of an On-line Geotechnical Instrumentation System for Monitoring Over the Internet

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Abstract

Since the establishment of the Mining Laboratories of Natural Resources Canada, in the early 1950s, rock mechanics has been one of its pre-eminent specializations. Our studies, conducted at many great Canadian mines, have included stress measurements; rock properties determinations; stress analyses; and mine monitoring. As the years have progressed, developments in both instrumentation and communications technologies have brought us from the point when written observations at individual instruments have been replaced by automated mine-wide monitoring systems. In this paper, the authors describe a state-of-the-art system that was installed, at NRCan's Mine-Laboratoire, Val-d'Or, Québec, for remote monitoring of extensometers and time domain reflectometry cables

Introduction

The earliest instruments used in rock mechanics and ground control were based on mechanical principles. Some examples of these were: (1) convergence rods, in which one rod slid within another; (2) mechanical extensometers, in which wires or rods connected between anchors and reference points at the head would move; (3) tape extensometers, to measure the precise distances between points; (4) stress measurement devices, such as the USBM (United States Bureau of Mines) device, in which the relaxation of a borehole would cause a piston, in turn connected to a spring-loaded cantilever, to move; (5) pressure cells, in which a fluid-filled cell would become increasingly pressurized with increased loads upon it; (6) Tell-tales and Ground Movement Monitors (GMMs), to indicate increasing movement across a discontinuity. These and others are described extensively in the literature that has accumulated since about the 1950s (Udd, 1986; Udd and Barthi, 1987). Many of these simple, inexpensive, instruments are in common use today.

Subsequently, with the advent of the strain gauge, electrical principles were applied. Stress measurements became simpler through the introduction of the CSIR (Council of Scientific and Industrial Research, of South Africa) "Doorstopper" and 3-Dimensional strain relief cells, and similar devices from elsewhere. Likewise, readings, which were once obtained longhand, could be obtained using simple electrical readout devices.

During the latter part of the 20th Century the introduction of the transistor, printed circuit technology, and miniaturization, and optical cables, made possible the development of much smaller and convenient instruments. The advent of underground communications systems, particularly fibre-optical-based systems made it possible for vast amounts of data to be transmitted, in addition to voice communications, from underground to distant locations. With today's multiplexing and satellite links it is possible to transmit messages and data from underground to almost any point on the earth's surface. Ground Control specialists can be alerted, through pagers and voice and data mail, to developments in their company's mines as these occur. The possibilities in the choice of an approach to mine monitoring are limited only by the degree of sophistication desired and the budget available.

In a previous paper, the authors described a mine-wide geotechnical monitoring system that was designed and installed at the Nanisivik lead-zinc mine on the southern shore of Strathcona Sound, at the northwestern end of Baffin Island (Udd et al., 2003). In that application, the system was designed to enable the transmission of data from extensometers in the underground mine to a computer in the mine offices.

In the present paper we describe a system that was installed at Natural Resources Canada's Experimental Mine, near Val-d'Or, Québec. This system brings further advances to the state-of-the-art in that the data obtained in the mine can be accessed at great distances - in this case at our Bells Corners Laboratory in the suburbs of Ottawa.

The Experimental Mine and the System

During the late 1980s and early 1990s, Natural Resources Canada acquired part of the surface facilities and access to the underground workings of the former Beacon 2 gold mine of Mines Aurizon Limited. Developed in the mid to late 1980s, this modern mine had been developed beside a former narrow-vein mine, the LeRoy, opened by LeRoy Gold Mines Limited for a short period during 1931-1932. The ramp allows access to both the small openings of the 1930s and the larger openings required for the mechanized equipment of the 1980s. The contrast between the old and the new is striking, and is a display in itself. The purpose of the Mine-Laboratoire (or Experimental Mine) is to permit full-scale experimentation in actual mining conditions. The focus is on mine mechanization and the development of advanced equipment and control systems.

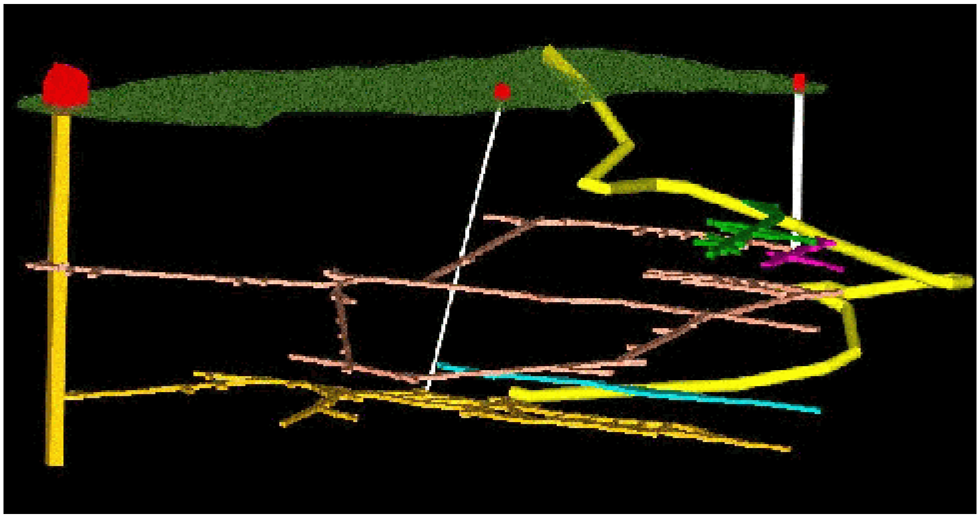
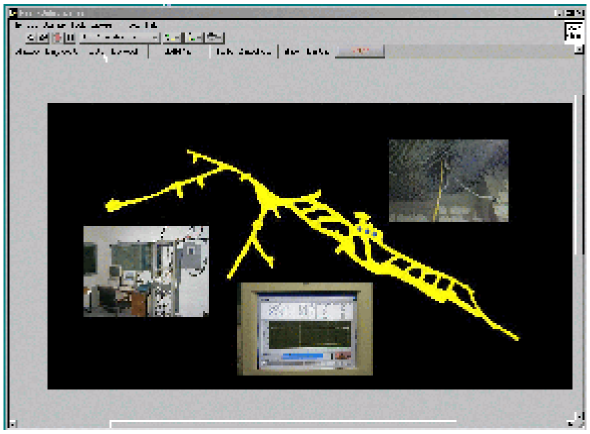
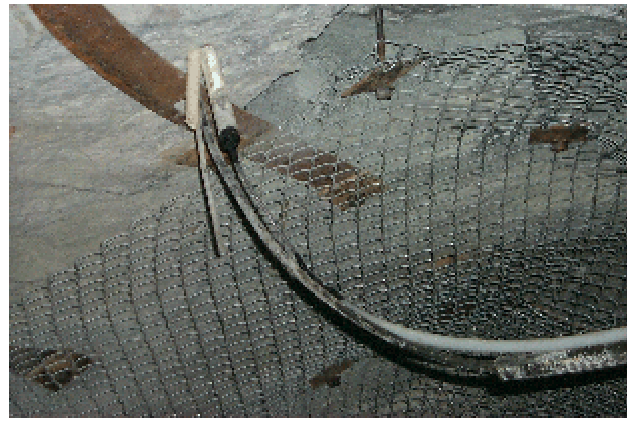


Figure 1: An isometric view of NRCan's Experimental Mine

An isometric view of the Experimental Mine is shown in Figure 1. In it, the old LeRoy shaft and the small levels associated with it are shown on the right of the figure, while the modern Beacon 2 shaft is shown on the left. During the development in the 1980s the new mine was developed to a depth of about 460 metres (with the lowest level at 430 m). In acquiring the rights of entry, CANMET had no requirement for either the shaft access or the lower levels. Thus, after acquisition, the mine was de-watered to just below the 130-m level, and the lower levels remain flooded.

During 2001 CANMET-MMSL (the Mining and Mineral Sciences Laboratories of CANMET) installed geotechnical monitoring instruments in three vertical holes which had been drilled, at strategic locations, into the back of what had once been intended to be a cut-and-fill stope to be developed upwards from the 130 metre level. The opening is presently used as a hydraulic laboratory. Figure 2 shows a plan view of the 130-metre level with the locations of the three holes and the monitoring station.

Installed and grouted in each of the three 9-metre holes were a 6-point Smart multi-point borehole extensometer, manufactured by Mine Design Technologies, of Kingston, Ontario, and an Eupen EC4-50, or similar, foam core 50-ohm radio frequency (RF) transmission cable (Figure 3). The former was installed to monitor the opening of cracks intersected by the holes, while the latter, a copper-clad aluminum inner conductor surrounded by cellular foam and a

Figures 2 and 3: Layout of the 130-m level (left) and an installation of cables (right)

ring-corrugated copper conductor with DURATHENE™ outer sheathing, was installed to be interrogated using Time Domain Reflectometry (TDR) techniques to monitor any possible shearing along the fractures in the back. The three TDR RF cables were multiplexed for use with a single readout, a Tektronix 1502C Metallic TDR Cable Tester, using an Autek Model 31 multiplexer. These instruments, and a fourth loose cable for demonstration purposes, were housed in a monitoring station installed in the former stope (Figure 4).

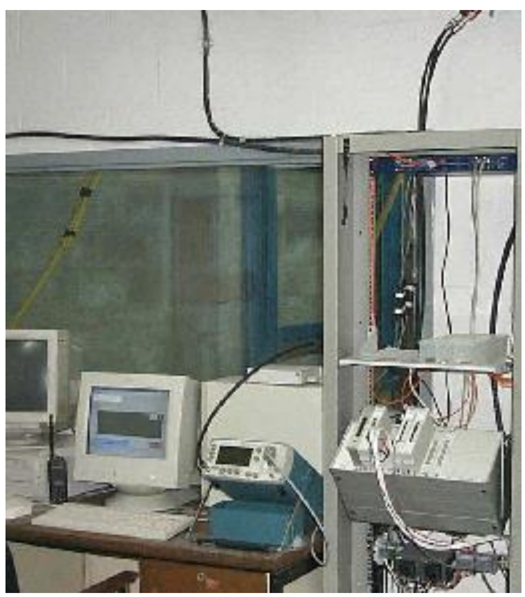


Figure 4: The underground monitoring station

In the monitoring station, a dedicated computer was used for the constant monitoring of the instruments and transmission of the data via a fibre optic Local Area Network (LAN) to any of the surface buildings at the Mine-Laboratoire, and, further, through a Wide Area Network (WAN) to the other units of MMSL, in Bells Corners and Sudbury, Ontario. Using National Instruments' Developer Suite - Professional Control Edition™ software (referred to here as LabVIEW™) the data could be displayed anywhere on the Wide Area Network, and, barring firewall limitations, to anywhere on the Internet. In the system, a National Instruments PCI-MIO-16E-4 multifunction input/output board was installed in the computer and connected to the multi-point extensometers, while the TDR cable reader was connected to the computer's RS-232 port (COM1). In addition, the multiplexer's control connector was connected to the LPT1 port of the computer. A schematic layout of the system is shown in Figure 5.

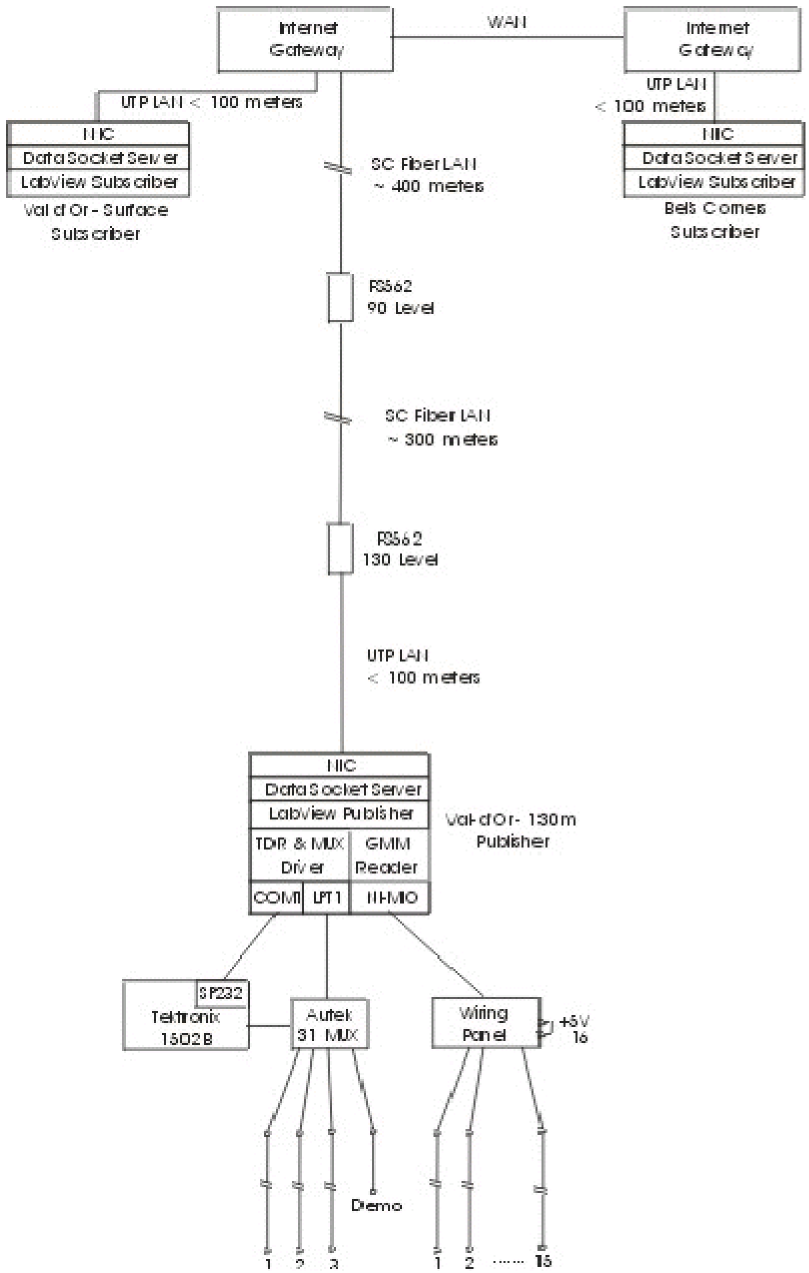


Figure 5: A schematic of the network installed at the Val-d'Or Experimental Mine

In the system the Tektronix 1502C Metallic TDR Cable Tester is used to acquire data concerning the impedance of the TDR cable along its length. This is accomplished by sending a pulse, with a fast rise time, down the cable. Whenever there is an impedance mismatch in the cable a portion of the pulse is reflected back to the instrument. The amplitude of the reflected pulse is expressed in mrho, where 1 mrho is 1/1000 of the initial pulse amplitude. Data is acquired one window at a time (called "binning"), with the windows being appended to each other to provide a complete waveform representation of the impedance versus distance in the cable. In practice, the number of bins to be collected depends on the length of the cable and the resolution at which it is to be scanned. Since this requires a number of instructions per bin the resulting array of data can be very large. Additionally, as is the present case, there can be several cables multiplexed at a single location. Thus, if each cable is scanned at different resolutions (1 mm and 1 cm in this case), considerable bandwidth can be required in order to transmit the instructions and receive the data.

In the Val-d'Or monitoring system a specifically written LabVIEW™ Virtual Instrument (VI) was used to handle communications between the Tektronix 1502B and the computer. Originally designed for field-based cable interrogations, it was stripped down, embedded in the laboratory computer, and used to control the 1502B and multiplexer. TDR cables can be used to detect changes, which take place as the result of tension, shear, or water infiltration. Our Virtual Instrument (VI) was used to compare baseline (initial) readings from the cables with current readings and to display the differences. In order to compensate for any instrument drift the driver computes the average difference between the two waveforms and subtracts it from the difference data (Figure 6).

In the Val-d'Or system the driver locates the maximum amplitude of the difference signal and the distance at which it occurs. While only a worst-case data, the provision of these to the surface, via the LAN, can alert the ground control engineer to a potential hazard. At this point the full waveform information from the cables underground can be uploaded to the surface and an interpretation made. Since about 10 minutes is required to scan the cables, the use of worst-case data significantly reduces the network bandwidth, which is required for transmission. The most recent data is always available, and is updated with every successive scan.

Another LabVIEW™ subroutine is used in parallel with the TDR driver to read the voltages from the multi-point extensometers. Each of these have been configured as voltage dividers, with baseline voltages being subtracted from the signals and a calibration factor applied to the difference to provide millimetres of movement since installation. Sensor and excitation voltages and the movement data provided to the surface via the LAN. This is done using National Instruments' TCP protocol called Data Socket Server™. Figure 7 shows the extensometer data as presented by the remote monitor or "Subscriber".

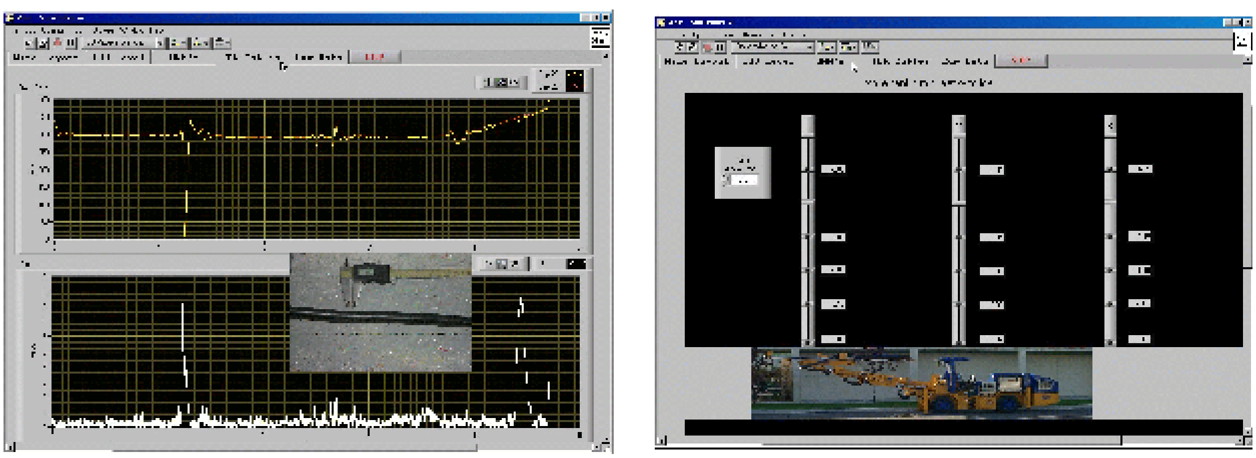
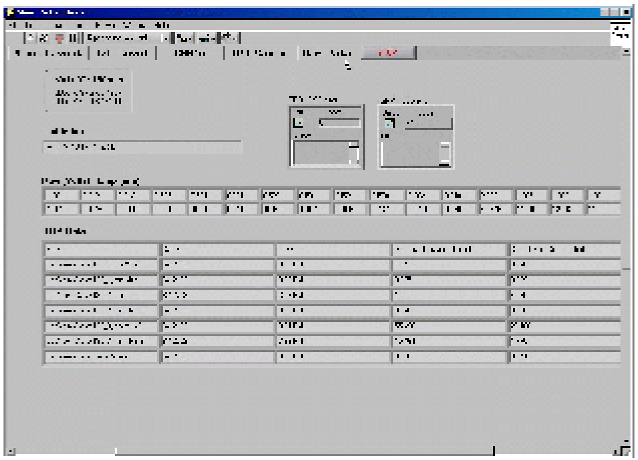


Figure 6 and 7: Typical TDR waveform (left) and extensometer display (right)

A "Publisher", in this case the computer on the 130 metre level at Val d'Or, "publishes" the data to the network (Figure 8). Elsewhere, "Subscribers", in the example illustrated, an engineer in Ottawa may "subscribe" to or read the data (Figure 9). Data Socket Server™ is "freeware", and our compiled "subscriber" routine, which displays this data, can also be readily distributed.



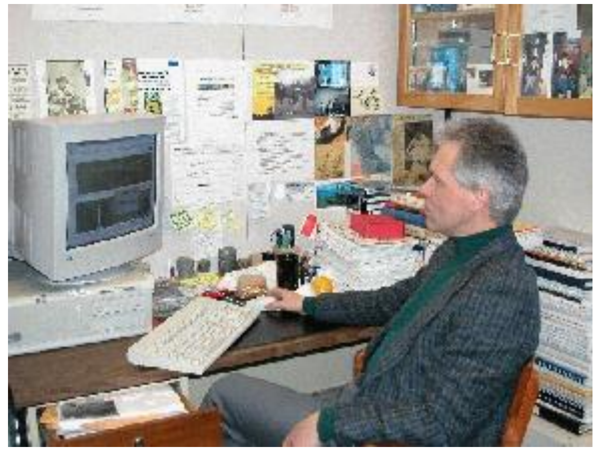


Figure 8 and 9: Published" data (left) and a geotechnical engineer, at Ottawa (right), accessing the data from Val d'Or

Conclusions

As has been demonstrated in this paper the staff of CANMET-MMSL of Natural Resources Canada has developed considerable expertise in the design and installation of mine-wide communications systems. This has been accompanied by the development of both hardware, software, and drivers that enable monitoring systems to access sensors, instruments, and loggers via the networks that are found in the mining industry. This "toolbox" can be used to solve many of the problems, which are encountered by the ground control engineer in his or her search for a monitoring system for geomechanics applications.

Biography

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Ken Judge received his Bachelors in Geology from Carleton University and his Electronics Engineering Technology Diploma from Algonquin College in Ottawa. Ken is a Senior Technologist with the Ground Control Program in Ottawa, Ontario as part of the Mining and Minerals Sector for Natural Resources Canada. Ken specializes in mining related instrumentation with emphasis on remote monitoring. Most recently, Ken has been developing techniques for remotely acquiring and quantifying Time Domain Reflectometry signals.

John E. Udd, FCAE, Ph.D., P.Eng.,
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John Udd received his Bachelors, Masters, and Doctorate degrees, in Mining Engineering, from McGill University, in Montreal. After teaching at McGill for several years, and progressing to Director of the Mining Program, he joined Falconbridge, in Sudbury, as Senior Ground Control Engineer. Appointed the Director of the Mining Research Laboratories of the Government of Canada, in 1984, he presently occupies the position of Principal Scientist. Dr. Udd has written extensively on various topics in rock mechanics, mining education, and mining history. He is a Fellow of both the Canadian Academy of Engineering and the Canadian Institute of Mining, Metallurgy and Petroleum.

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