MINING AUTOMATION

AUTOMATISATION DE L'EXPLOITATION MINIÈRE

II

PROCEEDINGS OF THE SECOND WORKSHOP SPONSORED BY CANMET/ MINING RESEARCH LABORATORIES

Sudbury, Ontario
October 17, 1986

PROCÈS-VERBAL DU DEUXIÈME COLLOQUE PARRAINÉ PAR CANMET/ LABORATOIRES DE RECHERCHE MINIÈRE

Sudbury, Ontario
17 octobre 1986

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Foreword

In 1985 a proposal was made, by the National Science Foundation of the United States of America, that an "International Centre for Research and Development in Innovative Systems of Remote Mining" be established in that country. CANMET, in its capacity as the mining research delivery vehicle for the Government of Canada, was requested to study the proposal and to prepare a Canadian response.

In doing so, it became evident that there was a need to obtain a national consensus of the views of the mining industry. The Canadian mining industry is both very large and very diversified. It is, therefore, extraordinarily difficult to attempt to agree upon, and attach priorities to, research needs.

Nonetheless, as a start, a consultative workshop (jointly sponsored by the Ontario Centre for Resource Machinery Technology) was held in Sudbury, Ontario on March 12, 1986. At that time, invited representatives of the mining and manufacturing industries, academia, and federal and provincial governmental departments, were asked to express their viewpoints and to see if agreement could be reached on a national plan of action. The "Proceedings" of that workshop were subsequently published as CANMET Special Report SP86-6.

The Workshop produced a number of desirable results. First, through bringing the stakeholders in mining automation together for the first time, a dialogue, which has since continued, was initiated. An "Ad-Hoc Committee on Automation in Mining" was formed by several of those present in order to maintain the momentum. That group subsequently organized a Canadian symposium on the subject, which was held in Sudbury, in October 1986. The group has also promoted the establishment of a specialized Canadian centre and may evolve into a permanent Advisory Board for that organization, after it has been started.

Secondly, the Workshop did make progress towards defining a national viewpoint. It was unfortunate, though, that there were no representatives present from several key sectors of the industry. Notably absent were representatives from open pit mines and quarries, and from coal, potash and iron mining. Because of their tremendous importance to the Canadian industry, any national view must involve input from these sectors.

This is essential not only because of the importance of their contribution to national output but also for strong technical reasons. It is principally in the bedded deposits and in the large volume open pit operations that developments in mining automation are taking place outside Canada. High rates of production and simplicity of mining geometries are almost prerequisites to achieving improved operating efficiencies through automation.

The viewpoint which arose from the Sudbury Workshop, therefore, being mostly based on the views of the hardrock metal mining part of the industry, was uniquely different in a worldwide context. The closest thinking to it would probably be found in Scandinavia — where the industry is very similar to Canada's hardrock mining sector.

Following the first Workshop, it became apparent very rapidly that another opportunity to bring a national viewpoint into sharper focus would arise shortly. With a Canadian symposium in the offing, it seemed likely that most of the stakeholders would be gathered, once again, at a common location.

Consequently, a second workshop was organized to follow immediately after the symposium. This was held, in Sudbury, on October 17, 1986.

Once again, however, there was almost no input from sectors of the mining industry other than hardrock metal mining. The academic community and the high-technology manufacturing industry, though, were both represented by greater numbers than at the first workshop.

At the conclusion of the second workshop it was agreed that there are strong needs for concerted national efforts in mining automation. It was not believed, though, that the industry would provide much direct support for efforts outside of Canada. There was a strong collective view that a world-class bank of data and information should be established in Canada. Further, it was emphasized that the national emphasis should be on industry-driven research.

This report contains all of the written submissions that were received in connection with the workshop. As in the case of the first one, not all of those present submitted texts of their presentations. Brief summaries of the principal points made, however, may be found in the "Minutes" of the meeting, which were prepared by Jay Pathak, of CANMET/MRL.

The collection, while less complete than hoped, represents another step in the definition of a national view. Efforts continue to be made to obtain the viewpoints of those who have not participated as yet in the sessions.

John E. Udd,
Ph.D., P. Eng.,
Director, Mining Research Laboratories,
CANMET

Avant-propos

En 1985, la National Science Foundation des États-Unis a proposé la création d'un centre international de recherche et de développement sur les innovations dans l'exploitation minière en région éloignée. Elle a demandé au CANMET, à titre d'organisme de recherche sur l'exploitation minière du gouvernement canadien, d'étudier cette proposition et d'élaborer la position du Canada sur la question.

Pour répondre à cette demande, le CANMET a constaté la nécessité d'obtenir un consensus national dans l'industrie minière canadienne. Étant donné l'étendue et la diversité de cette dernière, il est très difficile de tenter de s'entendre sur les besoins de recherche et d'établir leur ordre de priorité.

Néanmoins, le CANMET, en collaboration avec l'Ontario Centre for Resource Machinery Technology (OCRMT), a organisé un colloque de consultation qui s'est tenu le 12 mars 1986 à Sudbury. Lors de ce colloque, on a demandé aux représentants invités des secteurs minier et manufacturier, des universités et des ministères fédéraux et provinciaux, d'exprimer leurs opinions sur le sujet et d'examiner la possibilité de s'entendre sur un plan d'action nationale. Le procès-verbal de ce colloque a par la suite été publié dans le rapport spécial du CANMET SP86-6.

Ce colloque a donné un certain nombre de résultats souhaitables. Tout d'abord, en réunissant pour la première fois les principaux intéressés de l'automatisation de l'exploitation minière, on a amorcé un dialogue qui se poursuit toujours. Plusieurs participants ont formé un Comité spécial sur l'automatisation de l'exploitation minière afin de soutenir l'intérêt et, par la suite, ont organisé un symposium canadien qui s'est tenu à Sudbury en octobre 1986. De plus, ce groupe, qui a encouragé la création d'un centre canadien spécialisé, pourrait en venir à former un comité consultatif permanent pour le nouvel organisme créé.

En second lieu, le colloque a permis de mieux définir une perspective nationale sur l'automatisation dans l'exploitation minière. Toutefois, il était dommage que certains secteurs-clés de l'industrie, notamment ceux des mines à ciel ouvert, des carrières et des mines de charbon, de potasse et de fer, n'y étaient pas représentés. Pour refléter une perspective nationale, il faut obtenir le point de vue de ces secteurs en raison de la place importante qu'ils occupent dans l'industrie canadienne.

L'apport de ces secteurs est essentiel non seulement pour la contribution qu'ils apportent dans la production nationale, mais aussi pour des raisons d'ordre technique. Les progrès en matière, d'automatisation de l'exploitation minière dans les pays étrangers sont accomplis surtout dans les gisements en couche et dans les mines à ciel ouvert de grande échelle. Pour accroître l'efficacité de l'exploitation grâce à l'automatisation, les mines doivent presque indispensablement avoir des taux de production élevés et une géométrie simple.

Ainsi, le point de vue qui est ressorti lors du colloque était principalement fondé sur les opinions du secteur de l'abattage de gisements métallifères en roche dure et revêtait un aspect différent dans un contexte mondial. On pourrait probablement voir une ressemblance avec la Scandinavie où l'industrie s'apparente au secteur de l'abattage en roche dure au Canada.

Après ce premier colloque, il est vite devenu apparent qu'il y aurait prochainement une autre occasion de se pencher sur une perspective nationale. Puisqu'un symposium canadien était en vue, il semblait probable de pouvoir réunir de nouveau la plupart des intéressés.

Le CANMET a donc organisé un deuxième colloque qui s'est tenu immédiatement après le symposium, soit le 16 octobre 1986 à Sudbury.

Encore une fois, les secteurs de l'industrie minière n'étaient presque pas représentés, à l'exception de celui de l'abattage de gisements métallifères en roche dure. Par ailleurs, les représentants des universités et des fabricants de haute technologie étaient plus nombreux que lors du premier colloque.

À l'issue du deuxième colloque, les participants ont convenu de la nécessité absolue d'une concertation nationale en matière d'automatisation de l'exploitation minière. Toutefois, ils ne croyaient pas que l'industrie fournirait un appui direct pour les travaux réalisés à l'extérieur du pays. Ils étaient nettement d'avis qu'il fallait créer au Canada une banque de données et de renseignements à l'échelle mondiale. De plus, il a été souligné qu'il fallait surtout se concentrer sur la recherche menée par l'industrie.

Le présent rapport rassemble toutes les présentations écrites reçues parallèlement au colloque. Comme dans le cas du premier colloque, les participants n'ont pas tous remis un texte de leur présentation. Des résumés des principaux points soulevés lors des exposés figurent dans le procès-verbal, qui a été préparé par Jay Pathak du CANMET/LRM.

Bien que le compte rendu soit moins complet que nous l'avions escompté, il constitue une autre étape en vue de définir une perspective nationale en matière d'automatisation de l'exploitation minière. Nous continuons de déployer des efforts afin d'obtenir l'opinion des organismes qui n'ont pas encore participé au colloque.

John E. Udd, Ph.D., Ing.
Directeur, Laboratoires de
recherche minière, CANMET

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Sheraton Caswell Inn
1696 Regent Street South
Sudbury, Ontario

October 17, 1986

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   Dr. John E. Udd, Director, CANMET/MRL

2) Review of the Activities of the Ad Hoc Committee on Automation in Mining.

   Jacques M. Nantel, Chairman

3) Views and opinions of universities.

4) Views and opinions of manufacturers and consultants.

5) Views and opinions of the mining industry.

6) Views of government organizations.

7) Views of other organizations and individuals.

8) General discussion and concluding summary.

DEUXIÈME COLLOQUE SUR L'AUTOMATISATION DE L'EXPLOITATION MINIÈRE

ORGANISÉ PAR LE CANMET/LRM

Sheraton Caswell Inn
1696, rue Regent sud
Sudbury (Ontario)

Le 17 octobre 1986

ORDRE DU JOUR

1) Accueil des participants et mot d'introduction (antécédents, résultats du premier colloque, progrès accomplis, objectifs du deuxième colloque)

   John E. Udd, Directeur, CANMET/LRM

2) Revue des activités du Comité spécial sur l'automatisation de l'exploitation minière

   Jacques M. Nantel, Président

3) Vues et opinions des universités

4) Vues et opinions des fabricants et des experts-conseils

5) Vues et opinions de l'industrie minière

6) Vues des organismes gouvernementaux

7) Vues d'autres organismes et de particuliers

8) Discussion et sommaire

SECOND CANMET WORKSHOP ON MINING AUTOMATION

Minutes of the Meeting
Sudbury, October 17, 1986

BACKGROUND

This workshop was the second of two in which CANMET participated. The first, co-sponsored by the Ontario Centre for Resource Machinery Technology (OCRMT), was also held in Sudbury (on March 12, 1986). The minutes and the proceedings of that workshop have been published as CANMET Special Publication SP86-6.

The reason for holding this workshop was that the soft rock operators could not take part in the previous one. Secondly, there was a need to obtain additional focus in order to enable MRL/CANMET to formulate a policy regarding Canada's possible participation in the proposed foreign (USA) Centre for Automation of Mining and Tunnelling.

MINUTES

The workshop was chaired by Dr. J.E. Udd, Director of Mining Research Laboratories (MRL) of CANMET. He called the meeting to order and introduced himself and the other members of the MRL staff present. He then asked the other participants to introduce themselves.

He gave a short history of the Versailles Agreement and subsequent meetings with reference to mining automation and robotics for the benefit of those participants who did not attend the first workshop. He stated that through these workshops, he was asking for the consensus of the Canadian mining industry to report back on a Canadian position on mining automation. He then asked the participants to express their views.

Summaries of the key points from the individual presentations are as follows:

J. Nantel, Noranda Research

J. Nantel first spoke as Chairman of the Ad Hoc Committee on Mining Automation. He said that the committee has met regularly and has asked some organizations such as MAC, CATA, CIM, MEMAC, OMA, IEEE, CMEMA, CANMET, MOSST, NRC, and NSERC for endorsement. They have succeeded in getting this from some of them. The first priority of the committee was to organize a symposium on mining automation.This was held in Sudbury on October 16 and 17, 1986. He quoted the following goals of the Committee:

- — to promote development of automation in Canadina mining;
- — to coordinate efforts in mine automation, to avoid duplication;
- — to organize symposia;
- — to establish a forum for communication;
- — to recommend a Canadian position on mining automation for international purposes;
- — to propose a permanent structure;
- — to set priorities for the Canadian mining industry (with respect to automation).

He said that some action has already been taken to establish a Centre for Mining Automation at McGill and École Polytechnique in Montreal. They already have a Memorandum of Understanding in this respect.

The question of the future of the Committee was also discussed in a meeting held on October 16, 1986. It was decided that it should be continued as it is, as it is doing a good job. In the future, it might become an advisory body to the McGill/École Polytechnique Centre when it is established.

P. Pickerill, SPAR

The membership in the Ad Hoc committee will be reviewed to include representatives of other industry sectors presently not represented (e.g., softrock).

J.E. Udd, MRL/CANMET

He asked Jacques Nantel if he could write a report on what he said. The report would be a valuable addition to the proceedings of the meeting.

M. Scoble, McGill

They need an advisory body which defines problems and determines the goals for the Centre.

J. Wilson, OCRMT

The idea of an Ad Hoc committee is good but would it be representative? Will it have any clout?

M. Scoble, McGill

It will be set up on Walter Curlook's model and it should review itself as and when required.

A. Piche, École Polytechnique

So far there is no written proposal concerning the Centre, but it will be forwarded later to those who have an interest in it. The Centre will have a stong connection with the industry and will have an expertise of its own.

M. Scoble, McGill

They have the same objectives as École Polytechnique and they also have an agreement with respect to the Centre. He is hoping that the Webster Chair at McGill will be filled by Prof. J. Edwards, who is presently a visiting Professor. Their aim is to develop an Automation Centre for the mining industry.

G.A. Rubin, Laurentian University

They have a research group in place and would like to continue their research efforts in the area of basics of rock breaking. They are interested in high pressure waterjet technology for rock fracture – a field which has been disbanded at many places due to budget cuts. They are also working on acoustic resonance for the breaking of rocks.

A. Hall, UBC

He elaborated on a short list of research topics which are being carried out at the university. He would like to see a representation from the BC mining industry in the Ad Hoc committee. They also have a robotics and CAD department which can participate in the area of mining automation. He expressed his concern about the dissemination of information on these topics across the country. He gave an example that, in South Africa, there is a Mine Managers Club where information is exchanged at meetings.

W.G. Jeffery, CANMET

He said that in the last year there has been a dramatic change in Canadian thinking on mining automation. This is still in an evaluation stage, and UBC and other organizations will have roles to play.

W. Borowski, Wardrop Engineering

There is a role to be played by consulting engineers in this new field. They have experience in designing an automated materials handling system for nuclear waste repositories underground, and, therefore, knowing the mining industry, they can contribute to mine automation.

E. Card, Wardrop Engineering

The problem for the mining industry is to know what hi-tech companies have to offer and vice-versa.

P. Pickerill, SPAR

Spar had received a request from Carl Peterson to support the USA Centre at MIT, but had decided not to. He thought that the USA and Canadian Centres would be complementary and would not be working against each other. They would like to have a close link with the universities, as well as with the future Centre in Canada. He suggested that the Advisory Committee has to be industry-driven, and that they should have a leading role to play in deciding the goals of the Centre.

J. McCubbin, Martin, McCubbin & Associates

He agreed with Peter Pickerill's remarks and with the proposed establishment of a Centre at McGill/École Polytechnique. He said that a protocol in mining should be defined and established. He said that small mines should not be neglected for hi-tech or automation applications.

J.E. Udd, MRL/CANMET

The needs of small mines are special. They need special types of equipment, and have an important role to play in the development of a national position.

M. Scoble, McGill

McGill was approached by MIT and Penn State University to affiliate with them, but, as a Canadian Centre was in the offing, there was no point in joining them at this time.

B.A. Schaefer, Interact

Interact is a multidisciplinary R&D company and has developed an expert system for mineral exploration for a client in BC. It is applicable in different areas in the mining industry. For that, they will need the assistance of mine operators to define problems for them.

D. Ballantyne, Davis Engineering

He stated that the automation equipment described in the symposium (which had preceded the Workshop), was of a specific type, and not of a general type. There should be an overall realizable goal for automation in mines. If funds are available, then the Government, industry, and manufacturers should cooperate.

D. Perley, Control Devices Corp.

He said that he was attending the workshop for the first time. He then gave a summary of the activities of CDC, and said that they would like to apply their expertise to mine automation problems.

H. Licht, AECL

He emphasized the use of the remote manipulator arm and said that it should be absolutely reliable and that the technology could be applied elsewhere.

H. Jones, Mining Association of Canada, MAC

The membership of MAC is very large and can therefore represent the views of all the mine operators of Canada. They support the idea of a Canadian Centre and the objectives of the Ad Hoc committee. They are forming a group to evaluate the needs of the mining industry for technology.

M. Jowsey, HDRK

He said that metal mining is a relatively tiny industry in the world but large in Canada. Not many developed countries have such a large mining sector. HDRK is the single hardrock entity of its nature, beside the Chamber of Mines in South Africa.

B.B. Werden, Blackbox Controls

Blackbox exports radio remote controls for scooptrams and cranes and are very much interested in mine automation. They think that there should be a good underground test site in Sudbury, and for open pits, in the west. Mine operators must offer good cooperation for rigorous testing and there should be independent expertise to conduct and evaluate test results. It is essential that designers and manufacturers are guaranteed marketing rights.

G. Pike, Blackbox Controls

In his opinion, electronics and automation could be applied to mining by revolutionary or evolutionary methods. The practical method is evolutionary, applied step by step, and justified economically at each time.

In the first phase, remote control and radio remote control were designed. These were retrofitted. There are now more than 100 such units. Many machines, however, were custom designed, and cannot have a common design for retrofitted accessories.

In the second phase, feedback sensors, logic controls, AI and expert systems will be required to make equipment fully automated (to be run unattended). Closed circuit TVs could be used to operate more than one piece of equipment simultaneously.

D. Perley, CDC

He was of the opinion that TV monitoring has a much larger and more global application.

J. Nantel, Noranda Research

Noranda Research will support a Canadian research centre in mining automation and is not prepared to take part in another centre. He said that the Centre will have to be industry led, although NRC and CANMET will have a role to play by funding mining research and supporting other research important to mining industry. Small mine research support should be managed by NRC/CANMET.

G. Sauriol, Noranda Research

He stressed the importance of research to improve machine availability, which is becoming very costly. Preventive maintenance to avoid serious break-downs should have a priority for R&D.

J. Kelly, Inco Ltd.

He stated that he believes in revolutionary changes in mining methods and equipment. Radical changes in these areas are required and they should come very quickly. He was surprised at the level of funding allotted by Sweden, which was quoted by John Udd, for mining automation research. He proposed that some funds from MDA should be diverted in this direction. Inco also supports the establishment of a Canadian Centre for Mining Automation.

J.E. Udd, MRL/CANMET

He appreciated John Kelly's remarks regarding re-direction of MDA funds for research in mining automation. He also quoted from Carl Peterson's (MIT) paper suggesting that automation in mining needs a quantum leap.

W.G. Jeffery, CANMET

He agreed that MDA funds should be directed to areas which are more useful and productive, but, he said, these are put into projects which are recommended by advisory committees. Consultative methods of seeking guidance and direction now exist.

M. Jowsey, HDRK

Milt Jowsey said that he was speaking for the four companies involved in HDRK. These have priorities in the areas of continuous mining systems, reduction of cyclical operations, and development of mining methods which could be prone to automation. He believes in finding out first what is available in order to avoid costly duplication. Australian research is proceeding in an evolutionary way. He said that suppliers should give a guarantee for the performance of their equipment but that they are not prepared to do this.

L. Gregg, Falconbridge

He believed that equipment which works on surface will not necessarily work underground. Simple things have to be looked at in detail before inventing any complex technology. The equipment has to keep on running! The manufacturers are not enthusiastic to go underground. He asked if suppliers would go down and help run their equipment and maintain it?

He also said that there is a need for revolutionary thinking for management regarding automation.

H. Licht, AECL

He said that he works in the nuclear industry and that the problem of maintenance is minimized by over-designing of equipment. The reliability of their equipment is very high.

C. Mayer, OCME

He said that it is worthwhile for engineers to do life-cycle cost studies which will avoid future long delays.

P. Townsend, Denison

He would like to see a number of protocols in place. Denison Mines in Elliot Lake operates about 200 faces/ day. He said that an automated system may suffer from long delays if there is not progress in peripheral technology. For a fail-safe operation there still has to be an attendant.

For the nation, it is important to get into the business of production of equipment for automation, but it is a risky business. Operating companies should not take this on alone. The Canadian government should play a big role in it.

G. Zahary, RPO/CANMET

For a long time George Zahary was associated with the Coal Research Labs of CANMET. He said that he did not speak for coal mine operators, but, rather, as an individual. He noted that there are a few projects funded by CANMET, e.g., a fully integrated truck information system, from the USA, is being presently evaluated in collaboration with a coal mining company from western Canada. A Conspec system has been installed on a longwall face to monitor the environment. Manual monitoring is also carried out for comparison purposes.

P. Townsend, Denison

Peter Townsend said that coal and potash mines could provide a good test environment because the deposits are flat. In Canada, underground coal mining is almost dead at present.

J. Wilson, OCRMT

What concerned him was the level of funding in mine automation in Sweden in mine and hi-tech research. This could prove to be a big threat to Canada. He thinks that the Government should go the same way as Sweden. He thought that, in Sweden, the industry and the manufacturers are all national, therefore, it is possible to fund mining research to such an extent.

If another symposium on mine automation is to be held in Ontario, he said that the OCRMT will support it again.

C. Mayer, OCME

He asked a question regarding the funding of a Centre for Mining Automation. He proposed that some kind of forum should be established in order for mine operators, hi-tech firms, and manufacturers to keep a continuous dialogue among themselves. Before a revolutionary or evolutionary approach could be adopted for mine research, an overall systems approach has to be looked into.

He also asked the question of whether Canada should use Swedish-developed hi-tech and automation equipment for production, or get into this type of expensive research?

E. Cinits, CART

He and his organization support the Centre. He said that it should be industry-driven. His centre is looking into a cross-linkage between mining, forestry, and fisheries technology.

J. Scrimgeour, NRC

He was of the opinion that what is best for Canada as a whole should take precedence. He believed that not only existing sensors should be ruggedised, but that new ones should be developed too. He said that a major advancement in on-board micro-processors is taking place which could be applied to mining. It is very important to develop a fully integrated voice and data communications by them for mine organizations.

J. Edwards, McGill/Sheffield

He expressed his concern that the Japanese are investing in automation in mines in the third world and that could be a threat to Canada. He showed some slides on mathematical simulation of travel and cutting of coal face by coal cutting machines.

J.E. Udd, MRL/CANMET

He mentioned that CANMET is not involved with mine equipment design but that some related research might be funded. As regards the MDA programs, these are five-year programs. The directions of research are decided by operators and the various provincial mining associations.

P. Townsend, Denison

He was interested in getting information on CANMET research projects.

J.E. Udd, MRL/CANMET

The TID regularly sends out information regarding CANMET research projects and information on contracts to various companies. He invited those present to add their names to the mailing lists.

T. Pugsley, Falconbridge

They are short of people to handle and collect information on mine automation technology in the world. He suggested that the new Centre should also have a data and information gathering function, and distribute this to all mines.

P. Pickerill, SPAR

He believed that there is major deficiency in the infrastructure of Canadian mining. Sweden has to support only an in-house industry, whereas, here, we are not served by purely Canadian manufacturers. If Sweden can have a world-class manufacturing industry for such a small home market, why can't we?

M. Jowsey, HDRK

Sweden's domestic consumption is only 8% and 92% is exported. They have to pay 5% tax towards research. Atlas Copco and other manufacturers donate equipment for research and testing.

D. Perley, CDC

He suggested that there are a number of mines in Canada and a Crown Corporation could be formed: 1. to study project identification; 2. orchestrate development and coordination of ideas for mining hi-tech; 3. conduct testing of prototypes; and, 4. lease equipment to small mines through a pool.

T. Pugsley, Falconbridge

He said that we have to buy all foreign equipment. To run and maintain these we need to develop skills and to educate people.

M. Scoble, McGill

To gain first-hand knowledge, he said, we have to send people all over the world.

In his closing remarks, J. Udd said that the Proceedings of the workshop would be published and sent to all participants. He thanked the participants for their contributions. The meeting was adjourned at 1600 h.

DEUXIÈME COLLOQUE SUR L'AUTOMATISATION DE L'EXPLOITATION MINIÈRE
Procès-verbal de la réunion tenue le 17 octobre 1986 à Sudbury

ANTÉCÉDENTS

Ce colloque, le second du genre, constitue le deuxième auquel participe le CANMET. Le premier, co-parrainé par l'Ontario Centre for Resource Machinery Technology (OCRMT), s'était également tenu à Sudbury, le 12 mars 1986. Le procès-verbal et le compte rendu du premier colloque forment le rapport spécial SP86-6, publié par le CANMET.

Ce colloque a été organisé parce que les exploitants des mines de roche tendre ne pouvaient pas prendre part au premier. De plus, il fallait obtenir une autre perspective afin de permettre aux Laboratoires de recherche minière du CANMET d'élaborer une politique concernant la participation éventuelle du Canada dans le centre international sur l'automatisation de l'exploitation minière et du percement de tunnels, proposé par les États-Unis.

PROCÈS-VERBAL

J.E. Udd, directeur des Laboratoires de recherche minière (LRM) du CANMET, préside le colloque. Après avoir ouvert la séance, il se présente et présente les membres du personnel du LRM qui sont présents. Il demande ensuite aux autres participants de se présenter.

Afin d'éclairer les participants qui étaient absents lors du colloque précédent, il donne un bref historique de l'Accord de Versailles et un compte rendu des réunions qui ont suivi au sujet de la robotique et de l'automatisation de l'exploitation minière. Il souligne que ces colloques ont pour but d'obtenir un consensus de l'industrie canadienne en matière d'automatisation de l'exploitation minière en vue de présenter un rapport de la position du Canada sur cette question. Il invite ensuite les participants à exprimer leur point de vue à ce sujet.

SOMMAIRE DES POINTS-CLÉS DES PRÉSENTATIONS INDIVIDUELLES

J. Nantel, Centre de recherche Noranda

J. Nantel, à titre de président du Comité spécial sur l'automatisation de l'exploitation minière, précise que le Comité s'est réuni régulièrement et a demandé l'appui de certains organismes tels que l'AMC, la CATA, l'Institut canadien des mines et de la métallurgie, l'AMMEC, l'OMA, l'IEEE, la CMEMA, le CANMET, le MÉST, le CNRC et le CRSNG. Le Comité a réussi à obtenir l'appui de certains d'entre eux, mais il s'est surtout concentré sur l'organisation d'un symposium sur l'automatisation de l'exploitation minière.

Ce symposium a eu lieu à Sudbury les 16 et 17 octobre 1986. J. Nantel précise que le Comité s'était fixé les objectifs suivants:

- — promouvoir l'automatisation dans l'industrie minière au Canada;
- — coordonner les efforts en matière d'automatisation afin d'éliminer le chevauchement des travaux;
- — organiser un symposium;
- — créer un forum pour les échanges d'information;
- — recommander la position du Canada concernant l'automatisation de l'exploitation minière dans un contexte international;
- — proposer une structure permanente; et
- — établir des priorités au sein de l'industrie minière canadienne en ce qui a trait à l'automatisation.

Il fait savoir que des mesures ont déjà été prises en vue d'établir un centre d'automatisation de l'exploitation minière à l'Université McGill et à l'École Polytechnique à Montréal. Ces dernières ont préparé un mémoire d'entente sur cette question.

On a également discuté de l'avenir du Comité lors de la réunion du 16 octobre 1986. Il avait alors été décidé que le Comité ne devait pas être modifié étant donné qu'il faisait du bon travail. Le Comité pourrait devenir un comité de consultation pour le centre d'automatisation de l'Université McGill et de l'École Polytechnique lorsque celui-ci sera créé.

P. Pickerill, SPAR

La liste des membres du Comité spécial fera l'objet d'une révision en vue d'y ajouter des représentants d'autres secteurs de l'industrie qui n'en font actuellement pas partie (p. ex. les exploitants des mines de roche tendre).

J.E. Udd, LRM/CANMET

Il demande à Jacques Nantel de préparer un rapport écrit de son exposé. Ce rapport constituerait un ajout précieux au procès-verbal de la réunion.

M. Scoble, McGill

Il exprime la nécessité d'un comité de consultation qui définira les problèmes et précisera les objectifs du Centre.

J. Wilson, OCRMT

Bien qu'il trouve bonne l'idée d'un comité spécial, il s'interroge sur la représentativité de ce dernier. Le Comité sera-t-il influent?

M. Scoble, McGill

Le Comité spécial sera créé d'après le modèle de Walter Curlook et il devrait au besoin réviser son mandat et ses objectifs.

A. Piché, École Polytechnique

Jusqu'à présent, il n'existe pas de proposition écrite au sujet du centre, mais elle sera envoyée plus tard aux personnes intéressées. Le centre sera intimement lié à l'industrie et possèdera ses propres spécialistes.

M. Scoble, McGill

L'Université McGill a les mêmes objectifs que l'École Polytechnique, et ces deux établissements ont également conclu une entente relativement au centre. M. Scoble espère que J. Edwards, professeur invité, sera le titulaire de la chaire Webster de l'Université McGill. L'Université vise à mettre sur pied un centre d'automatisation sur l'exploitation minière.

G.A. Rubin, Université Laurentienne

L'Université Laurentienne possède un groupe de chercheurs et elle aimerait poursuivre ses recherches sur les fondements de l'abattage des roches. Elle s'intéresse à la technologie de fracture des roches par jet d'eau de haute pression, un domaine qui dans de nombreux endroits a été abandonné en raison de restrictions budgétaires. Les chercheurs effectuent des travaux sur la résonance acoustique en rapport avec l'abattage de roches.

A. Hall, UBC

Il apporte des précisions sur les divers sujets de recherche actuellement effectuée à l'Université. Il aimerait que l'industrie minière de la Colombie-Britannique soit représentée au sein du Comité spécial. L'Université possède un département de robotique et de conception assistée par ordinateur qui pourrait fournir un apport en matière d'automatisation de l'exploitation minière. A. Hall s'interroge sur la diffusion de l'information dans ces domaines au Canada et mentionne, à titre d'exemple, que les membres du Club des gestionnaires de mines en Afrique du Sud échangent de l'information lors de leurs réunions.

W.G. Jeffery, CANMET

Il précise qu'au cours de l'année, l'opinion des Canadiens sur l'automatisation de l'exploitation minière s'est considérablement modifiée. L'automatisation est encore au stade d'évaluation, et l'UBC et d'autres organismes auront un rôle à jouer.

W. Borowski, Wardrop Engineering

Les ingénieurs-conseils ont un rôle à jouer dans ce nouveau domaine. Ils possèdent de l'expérience dans la conception d'un système automatisé de manipulation de matériaux utilisé pour les dépôts souterrains de déchets nucléaires. Puisqu'ils connaissent ce secteur, ils peuvent contribuer à l'automatisation de l'exploitation minière.

E. Card, Wardrop Engineering

Le problème pour l'industrie minière est de connaître ce que les entreprises de haute technologie ont à lui offrir et inversement.

P. Pickerill, SPAR

La société SPAR a reçu une demande de Carl Peterson en vue d'appuyer le centre américain au MIT, mais elle a décidé de ne pas lui accorder son appui. P. Pickerill croit que les travaux des centres américain et canadien seraient complémentaires et que les deux centres travailleraient de concert. SPAR aimerait travailler étroitement avec les universités ainsi qu'avec le futur centre canadien. M. Pickerill dit que le Comité consultatif doit être mené par l'industrie et que ce dernier devrait jouer un rôle majeur dans la définition des buts du Centre.

J. McCubbin, Martin, McCubbin & Associates

Il partage les remarques de Peter Pickerill et approuve la création d'un centre à McGill et à l'École Polytechnique. Il soutient qu'il faudrait définir et établir un protocole dans l'exploitation minière. Il ajoute qu'il ne faut pas négliger les petites mines au profit des applications de haute technologie et d'automatisation.

J. Udd, LRM/CANMET

Les petites mines ont des besoins spéciaux. Celles-ci ont besoin d'équipement particulier et jouent un rôle important dans l'élaboration d'une position nationale.

M. Scoble, McGill

Le MIT et la Penn State University ont demandé à l'Université McGill de s'affilier à eux, mais puisque le centre canadien était en vue, il n'y avait aucune raison de se joindre à ces derniers à ce stade-ci.

B.A. Schaefer, Interact

Interact est une société de recherche et de développement multidisciplinaire. Elle a mis au point un système spécialisé d'exploration minérale pour un client de la C.-B., système qui peut être utilisé dans divers secteurs de l'industrie minière. Elle fera appel aux exploitants des mines pour définir les problèmes liés au système.

D. Ballantyne, Davis Engineering

Il fait remarquer que le matériel d'automatisation décrit lors du symposium (qui a précédé le colloque) n'était pas de conception générale mais plutôt spécifique. Il faudrait définir un but général réalisable en matière d'automatisation de l'exploitation minière. Si les fonds sont disponibles, il devrait y avoir une collaboration entre le gouvernement, l'industrie et les fabricants.

D. Perley, Control Devices Corp. (CDC)

D. Perley mentionne qu'il participe pour la première fois au colloque. Il donne un aperçu des activités de la CDC et précise que cette dernière aimerait appliquer ses connaissances techniques aux problèmes de l'automatisation de l'exploitation minière.

H. Licht, ÉACL

Il préconise l'utilisation du bras manipulateur télécommandé et indique que celui-ci devrait être tout à fait fiable et que la technologie pourrait s'appliquer à d'autres secteurs.

H. Jones, Association minière du Canada (AMC)

Puisque l'AMC compte de nombreux membres, elle reflète bien les points de vue de tous les exploitants de mines au Canada. Elle appuie la création d'un centre canadien et les objectifs fixés par le Comité spécial sur l'automatisation. Les membres sont en train de former un groupe en vue d'évaluer les besoins technologiques de l'industrie minière.

M. Jowsey, HDRK

Il précise que l'exploitation des métaux est une industrie relativement petite sur le plan mondial mais importante au Canada. Peu de pays industrialisés possèdent un secteur minier aussi important. HDRK est la seule société en son genre qui exploite des mines de roche dure, à l'exception de la Chamber of Mines en Afrique du Sud.

B.B. Werden, Blackbox Controls

La société Blackbox, qui exporte des télécommandes radio pour les grues et les chargeurs-transporteurs à godet, est très intéressée à l'automatisation de l'exploitation minière. Elle croit qu'il devrait y avoir de bons terrains d'essai pour les mines souterraines à Sudbury et pour les mines à ciel ouvert dans l'Ouest. Les exploitants des mines doivent être disposés à collaborer à la réalisation d'essais rigoureux, et des experts indépendants devraient diriger et évaluer les résultats des essais. Il faut assurer aux concepteurs et aux fabricants des droits de commercialisation.

G. Pike, Blackbox Controls

Selon G. Pike, l'électronique et l'automatisation pourraient être appliquées à l'exploitation minière en ayant recours à des méthodes révolutionnaires ou évolutionnistes. La méthode pratique, une méthode évolutionniste, est appliquée étape par étape et, chaque fois, est justifiée du point de vue économique.

Lors de la première étape, la commande à distance et la télécommande radio ont été conçues et remises à neuf. Il en existe maintenant plus de 100 unités. Toutefois, un grand nombre de machines ont été faites sur mesure, et il n'existe pas de modèle commun pour les accessoires remis à neuf.

Dans une deuxième étape, il faudra des capteurs de réaction, des commandes logiques, une intelligence artificielle et des systèmes spécialisés pour automatiser complètement le matériel, c'est-à-dire le faire fonctionner sans intervention humaine. Des télévisions en circuit fermé pourraient être utilisées pour faire fonctionner plus d'une machine à la fois.

D. Perley, CDC

Il est d'avis que la surveillance par télévision a une application plus vaste et plus globale.

J. Nantel, Centre de Recherche Noranda

Le Centre de Recherche Noranda appuyera un centre de recherche canadien en matière d'automatisation de l'exploitation minière, mais il n'est pas prêt à contribuer à un autre centre. J. Nantel dit que le centre devra être dirigé par l'industrie, bien que le CNRC et le CANMET aient pour rôle de financer la recherche minière et d'appuyer d'autres travaux de recherche importants dans l'industrie minière. Le CNRC et le CANMET devraient assumer une direction en ce qui a trait à l'appui fourni pour les travaux de recherche des petites mines.

G. Sauriol, Centre de Recherche Noranda

Il souligne l'importance de la recherche en vue d'accroître la disponibilité des machines qui deviennent de plus en plus coûteuses. Les travaux de recherche et de développement devraient porter d'abord sur l'entretien préventif afin d'éviter les pannes.

J. Kelly, Inco Ltd.

Il croit aux changements révolutionnaires dans les méthodes et le matériel d'exploitation minière. Des changements radicaux s'imposent dans ces domaines et devraient être apportés bientôt. J. Kelly est surpris d'apprendre par M. Udd l'importance des fonds affectés en Suède à la recherche sur l'automatisation des mines. Il suggère que certains fonds provenant des EEM soient employés à l'automatisation. Inco appuie également la création d'un centre canadien sur l'automatisation de l'exploitation minière.

J.E. Udd, LRM/CANMET

J.E. Udd apprécie les commentaires de John Kelly concernant l'affectation de fonds des EEM à la recherche sur l'automatisation de l'exploitation minière. Il cite un ouvrage de Carl Peterson du MIT qui indique que l'automatisation de l'exploitation minière doit réaliser des progrès importants.

W.G. Jeffery, CANMET

W.G. Jeffery convient que les fonds des EEM devraient être dirigés vers des domaines plus utiles et productifs, mais il précise que ces fonds sont affectés à des projets qui sont recommandés par les comités consultatifs. Il existe maintenant des méthodes de consultation qui visent à obtenir des conseils et une direction à suivre.

M. Jowsey, HDRK

À titre de porte-parole des quatre sociétés que HDRK représente, Milt Jowsey fait savoir que les secteurs prioritaires pour ces entreprises sont l'exploitation minière continue, la réduction des opérations cycliques et l'élaboration de méthodes d'exploitation minière susceptibles d'être automatisées. Il croit qu'il est possible d'éviter le chevauchement coûteux de travaux en s'informant sur ce qui existe déjà dans ce domaine. Les travaux de recherche en Australie progressent de façon évolutionniste. M. Jowsey déclare que les fournisseurs devraient donner une garantie sur le rendement de leur équipement, mais que ces derniers ne sont pas prêts à le faire.

L. Gregg, Falconbridge

Il soutient que le matériel utilisé en surface ne fonctionnera pas nécessairement sous terre. Avant d'inventer une technologie complexe, il faut étudier en détail certains aspects élémentaires. Le matériel doit continuer de fonctionner! Les fabricants ne sont pas très enthousiastes à l'idée d'aller dans les mines souterraines. L. Gregg se demande si les fournisseurs sont prêts à descendre dans les mines afin de les aider à faire fonctionner et à entretenir leur matériel.

Il souligne la nécessité de changer radicalement la façon de gérer les mines par rapport à l'automatisation.

H. Licht, ÉACL

Travaillant dans l'industrie nucléaire, il explique que le problème de l'entretien est réduit au minimum grâce à une conception très poussée du matériel. Le matériel de l'ÉACL est très fiable.

C. Mayer, OCME

Il fait ressortir qu'il serait avantageux pour les ingénieurs de faire des analyses des coûts du cycle de vie, ce qui éviterait des retards considérables à l'avenir.

P. Townsend, Denison

P. Townsend aimerait que soient mis en pratique un certain nombre de protocoles. Il dit que Denison Mines d'Elliot Lake exploite environ 200 fronts de taille par jour et précise qu'un système automatisé pourrait souffrir d'un retard considérable à défaut de progrès dans la technologie périphérique. Pour assurer une exploitation sans panne, il faut quand même avoir recours à une personne en service.

Il importe pour le Canada de commencer à produire du matériel pour l'automatisation, mais cette entreprise comporte des risques. Les sociétés d'exploitation ne devraient pas assumer ces risques à elles seules. Le gouvernement canadien devrait jouer un rôle très important dans ce domaine.

G. Zahary, BPR/CANMET

George Zahary a longtemps été associé aux Laboratoires de recherche sur le charbon du CANMET. Parlant à titre personnel et non en tant que représentant des exploitants des mines de charbon, il fait remarquer que le CANMET finance plusieurs projets, par exemple l'évaluation, en collaboration avec une société d'exploitation de charbon de l'Ouest canadien, d'un système d'information entièrement intégré pour les camions, système provenant des États-Unis. Un système Conspec a été installé sur un front exploité par longue taille afin de surveiller l'environnement. La surveillance manuelle est également effectuée à des fins de comparaison.

P. Townsend, Denison

Peter Townsend explique que les mines de charbon et de potasse pourraient constituer un bon environnement pour faire des essais étant donné que leurs gisements sont plats. À l'heure actuelle, l'exploitation souterraine du charbon est presque disparue au Canada.

J. Wilson, OCRMT

J. Wilson s'inquiète du fait que le niveau de financement, alloué par la Suède à l'automatisation de l'exploitation minière et à la recherche dans le secteur des mines et de la haute technologie, puisse constituer une menace pour le Canada. Il croit que le gouvernement canadien devrait suivre l'exemple de la Suède. Selon lui, en Suède, les industries et les fabricants sont entièrement nationaux, or il est possible de financer la recherche minière dans une aussi large mesure.

Il ajoute que si un autre symposium sur l'automatisation de l'exploitation minière devait avoir lieu en Ontario, l'OCRMT apporterait son appui encore une fois.

C. Mayer, OCME

C. Mayer a posé une question au sujet du financement d'un centre sur l'automatisation de l'exploitation minière. Il propose l'établissement d'un forum quelconque afin d'entretenir un dialogue entre les exploitants de mines, les sociétés de haute technologie et les fabricants. Avant qu'une approche révolutionnaire ou évolutionniste ne soit adoptée concernant la recherche minière, il faut étudier une approche globale des systèmes.

Il demande également si le Canada doit utiliser le matériel suédois de haute technologie et d'automatisation pour la production ou entreprendre de coûteux travaux de recherche du même genre.

E. Cinits, CART

E. Cinits, de même que l'organisme qu'il représente, appuient la création d'un centre. Il ajoute que celui-ci devrait être dirigé par l'industrie. Le CART étudie actuellement les recoupements entre les technologies utilisées dans le domaine de l'exploitation minière, de l'exploitation forestière et des pêches.

J. Scrimgeour, CNRC

Il soutient que ce qui est profitable pour le Canada dans son ensemble devrait avoir préséance. Il est d'avis qu'il faudrait non seulement rendre les capteurs existants plus solides, mais en concevoir de nouveaux. J. Scrimgeour signale que les microprocesseurs intégrés sont plus perfectionnés et pourraient être utilisés dans l'exploitation minière. Il est très important de mettre au point un système de communications en téléphonie et de transmission des données pour les organisations minières.

J. Edwards, McGill/Sheffield

Il se préoccupe du fait que les investissements des Japonais dans l'automatisation des mines du tiers monde puissent constituer une menace pour le Canada. Il montre des diapositives illustrant la simulation mathématique du déplacement et de l'abattage d'un front de taille de charbon à l'aide d'engins d'abattage du charbon.

J.E. Udd, LRM/CANMET

Il mentionne que le CANMET ne participe pas à la conception de matériel d'exploitation minière mais que certains travaux de recherches connexes pourraient être subventionnés. Quant aux programmes d'EEM, ils ont une durée de cinq ans. Ce sont les exploitants et les diverses associations minières provinciales qui décident de l'orientation de la recherche.

P. Townsend, Denison

Il est intéressé à recevoir de l'information sur les projets de recherche du CANMET.

J.E. Udd, LRM/CANMET

La Division de l'information technologique fait régulièrement parvenir à différentes sociétés de l'information sur les projets de recherche du CANMET et sur les contrats. J.E. Udd invite les participants à ajouter leur nom aux listes d'envoi.

T. Pugsley, Falconbridge

La Falconbridge n'a pas suffisamment de personnel pour recueillir et garder à jour l'information sur la technologie reliée à l'automatisation de l'exploitation minière dans le monde. Il propose que le nouveau centre ait comme fonction de recueillir les données et les renseignements et de les diffuser à toutes les mines.

P. Pickerill, SPAR

Il croit qu'il y a des lacunes importantes dans l'infrastructure de l'industrie minière au Canada. La Suède n'a qu'à soutenir une industrie intérieure, alors qu'au Canada, les fabricants ne sont pas uniquement canadiens. Si la Suède peut avoir une industrie manufacturière de classe mondiale pour un si petit marché intérieur, pourquoi le Canada ne pourrait-il pas en faire autant?

M. Jowsey, HDRK

La consommation intérieure de la Suède n'est que de 8 %, alors que les exportations se chiffrent à 92 %. Une taxe de 5 % est perçue pour la recherche. Atlas Copco et d'autres fabricants donnent du matériel pour la recherche et les essais.

D. Perley, CDC

Il suggère qu'en raison du grand nombre de mines au Canada une société de la Couronne soit créée pour remplir les fonctions suivantes : 1. définir le projet; 2. orchestrer l'élaboration et la coordination des idées en matière de haute technologie dans l'exploitation minière; 3. faire des essais sur les prototypes; et 4. louer le matériel aux petites mines par l'intermédiaire d'un fonds commun.

T. Pugsley, Falconbridge

Il précise que nous devons acheter tout le matériel à l'étranger. Pour faire fonctionner ce matériel et en assurer l'entretien, il faut développer les compétences et former les travailleurs.

M. Scoble, McGill

Selon M. Scoble, pour acquérir des connaissances de première main, nous devons envoyer des personnes partout dans le monde.

En guise de conclusion, J. Udd informe les participants que le procès-verbal du colloque sera publié et leur sera ensuite envoyé. Il remercie les participants de leur contribution. La séance est levée à 16 h.

REVIEW OF THE ACTIVITIES OF THE AD HOC COMMITTEE ON AUTOMATION IN MINING

Jacques H. Nantel,
Chairman

INTRODUCTION

Following the First Workshop on Mining Automation organized in Sudbury, Ontario, on March 12, 1986, by CANMET and the Ontario Centre for Resource Machinery Technology (OCRMT), the participants from the mining industry, equipment manufacturing, hi-tech firms, universities and governments decided to form an Ad Hoc Committee on Automation in Mining.

FIRST MEETING

The Committee went into action immediately and organized a first meeting which was held on April 18, 1986, in Pointe Claire, Québec. At this meeting three main topics were discussed for action: i) the Committee's modus operandi, temporary nature, future organization, relationship with other mining-related organizations, membership of the Committee, type of activities, ii) Canadian Workshop on Mining Automation, iii) Canadian Centre on Mining Automation and Robotics. It was decided that the Committee would organize a major Symposium on Mining Automation in 1986 and that work would begin on this task immediately.

At the first meeting the goals and objectives of the Committee were set:

i) to promote the development and use of automation in Canadian mining,

ii) to provide a forum for communication among users,

iii) to coordinate efforts on mining automation between national and international organizations,

iv) to establish priorities for research and innovation reflecting the mining industry's present and future needs,

v) to propose a permanent structure for the establishment of a Canadian Research Centre in Mining Automation,

vi) to organize a major symposium on mining automation in 1986,

vii) to help formulate a Canadian position on international cooperation on mining automation.

It was also decided to seek the moral support of several Canadian mining organizations. The following organizations were canvassed: MAC, CANMET, OCRMT, CATA, CIM, CART, MEMAC, OMA, QMMA, IEEE, CMA, MOSST (NRC & NSERC).

A short document outlining the goals of the Committee was prepared for distribution at the CIM Annual General Meeting held in Montreal in May, 1986.

It was also decided to prepare a paper for presentation at the Second International Conference on Innovative Mining Systems to be held at Pennsylvania State University, October 27-29, 1986.

FORMATION OF CENTRE FOR MINING AUTOMATION

The Chairman, accompanied by Dr. Walter Curlook, President of the Mining Association of Canada, visited on May 11 and 12, 1986, representatives from École Polytechnique and McGill University, to discuss with them the possibility of the formation of a Centre for Mining Automation.

On September 3, 1986, representatives from École Polytechnique (Dr. Vladimir Paskievici, Director of Graduate Research, Dr. Gaston Pouliot, Head, Department of Mineral Engineering), McGill University (Dr. Pierre Bélanger, Dean, Faculty of Engineering, Dr. John Gruzleski, Head, Department of Mineral Engineering and Dr. Malcolm Scoble, Professor, Department of Mineral Engineering), QMMA (Dr. Claude Drouin), MAC (Mr. George Miller) and Jacques Nantel, Chairman of the Ad Hoc Committee met to discuss the modalities leading to the formation of a Centre for Mining Automation and Robotics in Montreal.

SECOND MEETING

The second meeting of the Ad Hoc Committee was held in Ottawa, on May 31, 1986, to finalize the Symposium on Applications of Automation in Mining – Present and Future.

SYMPOSIUM ON MINING AUTOMATION

The First Symposium on Applications of Automation in Mining – Present and Future was held in Sudbury, October 14, 15 and 16, 1986. The Symposium was organized by the Canadian Ad Hoc Committee on Automation in Mining, with the strong sponsorship of OCRMT.

The Symposium attracted a surprisingly large number of participants (close to 200) from all over Canada, and a few from the USA and Europe (the publicity had been done exclusively in Canada). The participants were from the mining companies (45%), equipment manufacturers (15%), hi-tech firms, consultants (25%), universities (7%) and governments and NRC (8%). The participants ranged from the senior executives of the companies, high-ranking civil servants, to the technical people involved in hi-tech projects for the mining industry, etc.

The topics covered offered a variety of case studies describing work on-going and some research and development with potential applications in the near future (see Appendix 1, Table of Contents).

Two panel discussions addressed important implementation aspects of this technology: i) Technology Transfer, and Promoting Automation in Canadian Mining. The participation to both of these panel discussions was lively and generated a great number of thought-provoking statements.

The industry has to lead the movement, by developing a model for moving quickly, and set up an organization that will contain mechanisms for transferring the existing know-how, that will bring the specialists from various disciplines together and will generate new knowledge for future applications.

The formation of a Mining Automation Centre at McGill-École Polytechnique was endorsed by all and the Ad Hoc Committee was viewed as the ideal Advisory Committee for this centre. It is about time Canada has such an organization for such a vital sector of its economy.

The general mood was positive but some expressed the opinion that the mining industry may not be moving quickly enough, we need to embark on new "S-Curves" with new technologies in order to better compete internationally.

The message for the Canadian Mining Industry is clearly that we cannot stand on the side-line and watch the parade go by. The topic of automation in our mines should be addressed on a corporate scale and a plan of action arrived at. This strategy should:

i) Assess where we are: list the areas where we are involved;

ii) Formulate targets consistent with our corporate situation;

iii) Make a plan on how to achieve these objectives;

iv) Implement the plan.

The attendance at the Symposium remained strong to the very end and the comments from some participants were that this was the best symposium they ever attended. Several suggestions were made to hold another symposium next year; this decision will be left with the Ad Hoc Committee and OCRMT.

THIRD MEETING

The third meeting of the Ad Hoc Committee was held in Sudbury on October 16, 1986. At this meeting the following resolution was passed:

> "The Ad Hoc Committee on Automation in Mining strongly endorses the proposal for the establishment of a Centre for Mining Automation and Robotics at McGill University and École Polytechnique in Montreal. Furthermore, the Ad Hoc Committee expresses its willingness to act in an advisory capacity to this new Centre."

It was also decided to keep the Committee in its present form until a more adequate structure could be found.

Over the next few months the Committee will be active in helping with the formation of a Canadian Centre for Mining Automation.

The list of members of the Committee can be found in Appendix 2. It is the intention to expand the list as the requirements arise and to ensure adequate representativity from all interested players.

CLOSING REMARKS

Mr. Chairman, the consensus appears to be that the mining industry cannot look back and has to embark into the automation era in a big and coordinated way. The industry has to lead this movement and this Ad Hoc Committee will endeavour to do all it can to meet this goal.

VIEWS AND OPINIONS OF THE UNIVERSITIES

ULTRASONIC CUTTING OF SUDBURY HARD ROCKS

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Centre in Mining and Mineral Exploration Research (CIMMER)
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ROCK CHARACTERIZATION AND CUTTING OF HARD ROCKS

The task of primary rock fragmentation is usually accomplished by drilling and blasting operations, whereas soft rocks are mined by continuous cutting machines which permit the cyclic drill and blast operations to be replaced by a continuous unit, which cuts, loads and transports the ore from the mine face. At present, however, the technology is not available for continuous excavation of hard rocks, although there is considerable incentive in terms of increased productivity, safety and economy to achieve this goal.

For the development of a continuous rock excavation system, the foremost prerequisite is the understanding of the material to be cut (1). In order to accomplish this objective, the study has been initiated to characterize rocks in the Sudbury basin according to their resistance to cutting. A sample of the initial results is presented in Tables 1 and 2 together with the mineralogical and textural characteristics of the materials studies.

The generation of the data along these lines and subsequent analysis will facilitate the understanding of the rock's resistance to continuous excavation systems, utilizing both mechanical and novel cutting techniques.

CIMMER ULTRASONIC RESEARCH PROJECT

One of the novel techniques pursued at CIMMER's physics laboratory is the fragmentation of hardrock by sonic or ultrasonic resonances. To our knowledge, the only published record on an attempt to fracture rock by high frequency cyclic loading originated at the U.S. Bureau of Mines' laboratories in Minneapolis, about ten years ago. These studies fell victim to budget cuts (2).

It has been shown in our laboratory that sonar or ultrasonic resonances generated in three types of very hard Sudbury rock lead to local stresses exceeding the tensile strength of the rock and hence cause failure of the rock at an energy input per newly created rock surface which is significantly below the energy input necessary to fracture hard rock by other novel techniques (jet, laser, electron beam). The rock materials used in this study include two greenstones, one morite (igneous mineralogy), a partially recrystallized morite and two metamorphosed granodiorites. Hornblende and plagioclase feldspar are the dominant mineral phases in the greenstones. One sample is weakly foliated and medium grained; the second is uniformly fine-grained and exhibits a graoblastic polygonal texture. Plagioclase and two pyroxenes form the igneous mineralogy of the morites; granophyre is an interstitial intergrowth between randomly oriented medium-coarse-grained crystals of these phases. In one sample, the pryoxenes are completely replaced by hornblende. Both granitic samples are quite thoroughly recrystallized grandodiorites. Plagioclase and hornblende/biotite crystals enclosed within Kspar and quartz formed the initial igneous assemblage; recrystallization has formed a fine-medium grained, granoblastic polygonal, aggregate of felsic minerals. These studies have also provided us with valuable information on mechanical and thermal strain buildup prior to rock failure on a millisecond time scale.

The aim of our studies is the generation of resonance or near-resonance conditions in the rock face where high power, high frequency pressure waves are reflected back and forth between discontinuities of flaws or inclusion-boundaries in the rock. The equipment needed for the generation of high power at high frequencies could easily be installed and remotely controlled underground. The high power transducers to be used at the rock face in an optical arrangement are relatively small and could perhaps be operated in an automatic fashion. The results of our research and development work will soon be published.

REFERENCES

1. D. Goldsack, G. Rubin, M. Leach, P. Singh, R. James, P. Lindon, R. Prudhome "Development of Continuous Cutting Machines and the Variables Influencing the Cuttability of Sudbury and Other Hardrocks". Mining Automation CANMET Special Publication SP86-6, 1986.
2. P.J. Cain, S.S. Peng, E.R. Podnieks, "Rock Fragmentation by High Frequency Fatigue", U.S. Bureau of Mines, R.I. 8020, 1975.

TABLE 1. ROCK TYPES AND PHYSICAL PROPERTIES.

Sample Identification	Compressive Strength (MPa)	Compressional Wave Velocity (Kms/Sec)	Rock Type
308A	267	4.73	Hornblende-Biotite Gneiss
502B	106	5.34	Biotite Gneiss
322A	215	5.43	Hornblende Biotite Gneiss
608A	235	4.51	Foliated Granodiorite
632A	228	4.91	Foliated Granodiorite
902A	235	4.81	Foliated Granodiorite
924A	188	4.91	Matagranodiorite
1102A	226	4.04	Metagranodiorite
1109B	252	5.23	Foliated Granodiorite

TABLE 2. MINERALOGY OF ROCK SPECIMENS

	Quartz	Plagio-clase	K Feldspar	Horn-blende	Biotite	Muscovite	Epidote	Sphene	Opaque Minerals	Carbonate
308A	*	*	″	*	*	″	″	″	″	
502B	*	*	″		*	″		″	″	″
322A	*	*	″	*	*	″	″	″	″	
608A	*	*	*		″	″			″	
632A	*	*	*		″	″			″	
902A	*	*	*		″		″		″	
924A	*	*	*		″			″	″	
1102A	*	*	*		″	″	″		″	
1109B	*	*	*		″	″	″		″	

* = major minerals
″ = minor and trace minerals

FUTURE DIRECTIONS IN AUTOMATION IN MINING

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University of British Columbia

1. U.B.C. POSITION

A brief description of the Department and current research projects in mining is attached for information.

In the automation and process control field the work done by Professor Mular in mineral processing is well known and research is ongoing in the new coal and mineral process laboratory.

The work performed by Professor Hall in conjunction with Sherritt Gordon's Ruttan Mine in Manitoba is more recent. The objective of this project is to design an on-line mine ventilation monitoring and control system which will recirculate exhaust air into the mine intake air when the quality of the exhaust air permits this. The preliminary study at Ruttan indicates that 25% of the exhaust air can be recirculated on a 24 hour basis. The heating bill for Ruttan is $1m per annum so the potential saving is $250,000. Latest estimates indicate that the cost of a working system would be less than $500,000 giving a 2 year payback. Work on the system design is well advanced and application for funding has been submitted by Sherritt Gordon. We believe that we are in the forefront of this technology and should continue to develop automatic monitoring and control technology for mine ventilation. This field offers short payback periods and significant cost savings.

Robotic, CAD and automated control expertise exists in several other applied science departments and is available to mining projects.

2. BRITISH COLUMBIA NEEDS

B.C. mine operators have carried out considerable research in house to develop "asset technology" e.g., Lornex and Quintette Coal. Lornex conducted fuel consumption tests and shovel bucket load module testing to maintain a competitive edge in the copper production field. They have been reluctant to use University research facilities for such work because of the open publication of results required, especially in graduate work.

UBC have met with the B.C. mines inspectorate to try to determine research requirements perceived by them in the mining industry. Financial restraint within the Ministry has severely limited this initiative. Recent cabinet changes and the upcoming general election have created a lack of continuity in the Ministry. This position will be rectified by the end of October when a new Minister is confirmed in office.

The Mining Association of B.C. has also undergone change and Placer's A. Petrina has temporarily headed the association following the resignation of Tex Enemark until the recent appointment of Tom Waterland, the former Minister of Forests.

These changes in government and industry representation have occurred at a critical period for the industry. Unfortunately, the research needs of industry have not been defined and priorized by the representative bodies. E. Cinits of CART and myself have undertaken to attempt to arrange an early meeting between government, industry and the Universities with CART to priorize research needs on a market basis. This is clearly a priority.

The majority of B.C. mining is open pit and the perceived needs are improvement of mining operations to increase profit. Porphry copper mines operate at grades below 0.5% and their operating positions are tenuous. Decreases in world coal prices are also significant for B.C Mines.

In order to overcome these problems the following automation research areas can be identified:

1) Automation of open pit drilling operations with concurrent analysis of rock hardness to enable the mine to optimize its ore handling to provide a good mix of hard and soft ore to the mills to optimize grinding. Drills in open pits are capable of complete automated positioning and control on fixed pattern blasting.
2) Control of crushers and conveyors which are being used to replace truck haulage — Gibraltar, Valley and Island Copper.
3) Development of a continuous automated rock handling system from the pit to the mill.
4) On board control of shovels and draglines to improve performance.
5) Automation of rock stability measurements to improve wall stability and reduce failures.

It is essential that British Columbia's mining industry should receive a fair allocation of the federal resources available. The creation of the robotics chair at McGill and the rock mechanics cooperation between Queen's and Laurentian are excellent initiatives. It is critical that further initiative is provided for the Western Universities. Strong links exist between both UBC and the University of Alberta with the mining industries of Saskatchewan, Manitoba, Yukon and the Northwest Territories. It is essential that a cooperative association be developed between the industry, manufacturers and universities of the Western Provinces to provide direction for research. The advanced material technology unit at Queens could serve as a model structure on which to base the cooperative association. The five features which should be adopted are:

a) Regularly scheduled workshops in areas of concern to the University and industry members. (Initiatives with CIM so far have had disappointing industrial response.)

b) Appointment of faculty members as liaison officers to participating companies (must be sanctioned by the university and funding is required to travel to mines and/or industries).

c) Utilization of University facilities and expertise.

d) A specialized program of graduate studies and short courses (this can be readily arranged through the UBC M.Eng. Program).

e) Organization of research seminars, shared equipment, contracts and technical support.

Establishment of such an organization must be given high priority. Cooperation between UBC and CART must be improved as a matter of urgency to establish cooperative strategy.

3. PERSONAL OPINIONS

The following opinions are personal and are not necessarily those of UBC or other members of the faculty of applied science.

I agree that the mining industry is on a war footing which implies a shortage of trained manpower to handle change and a shortage of resources, particularly finance. Operations research and management science were developed during the 1939-45 period to optimize the use of scarce resources and it is imperative that these techniques be applied to mining automation and research to priorize projects and allocate resources.

New technology development must be accompanied by improvement in industrial practice. Blue Taylor of PCS referred to the $19 seat on the $13M machine. The American Institute of Industrial Engineers have identified the resource industries — mining, forestry and agriculture as the employers of the smallest percentage of industrial engineers (less than 1% of total engineering employees) of all industries in the United States. In 1982 Alexander and Smith presented an abbreviated checklist of ergonomic considerations for use in industry. These factors indicated a need for Human Factors Engineering Evaluation:

a) high absenteeism on task

b) high labour turnover on task

c) low production efficiency

d) frequent employee complaints about task

e) personnel assignment to task limited by age, sex or body size

f) long training time required

g) low quality product

h) excessive accident incidence on task

i) excessive material waste

j) excessive damage of equipment

k) frequent mistakes by worker

l) operator frequently away from his or her workplace

m) work place utilized on more than one shift per day.

I submit that these factors can be used as a checklist for priorizing mining tasks for potential automation. The aspects of safety and productivity are paramount in this process. Automation of coal face longwall operations has been well accepted in Europe because it removed dangerous, uncomfortable hand-loading jobs. Jumbo drilling has similar acceptance in preference to hand drilling at the face. I believe that the use of industrial engineering techniques to evaluate mining tasks can provide a low cost initiative which will achieve improvements in existing work practises and enable market driven priorization of automation research.

Exposure of engineers to new techniques is important. In 1985 the third-year UBC mining students were able to visit West Germany because of the German Academic Exchange Program (DAAD). In two weeks they visited four mines, a rail tunnel construction project, four equipment manufacturers, two industrial research facilities and the Aachen University. The cost of the visit appoximated $1500 per person, after funding from UBC award organizations (Keyes fund, Gage, Bucharan and AMS funds) the cost to each student was $150 because DAAD covered hotel and breakfast costs. I believe that we must encourage more technical exchange to promote the knowledge of new technology. Canada can arrange to host international mining conferences in the same aggressive way that they are promoted by the S. African government and Chamber of Mines. The hoisting conference arranged for Toronto in 1988 is an excellent initiative but we must regularly host APCOM, IFAC and the Commonwealth mining conferences if we are to maintain current technological expertise.

The role of the Universities in this field is extremely important. Much new technology is adopted by industry and then becomes known to the Universities, resulting in delays in amending teaching curricula. This is inevitable in mining with the small number of faculty and the information explosion. It is impossible for faculty to read all current journals in their field, especially during term times. Much information is also published in non-mining journals and is not always received. Funding restraints on libraries have drastically reduced the periodical purchases by Universities and the high cost of some periodicals has resulted in their being dropped from the library. Inter-library loans cover this but may take six to eight weeks to obtain the required information. Libraries of excellence must be maintained on a regional basis to disseminate knowledge and minimize duplication of research effort.

University research must be stepped up as it makes the university a leader in teaching, not a follower. The availability of equipment purchased under research monies for use in teaching undergraduates also improves the quality of education. It is therefore critical that the amount of mining research undertaken in universities should be increased significantly through initiatives to mining and manufacturing companies to be involved in joint projects. Western universities must be included in this expansion. Travel costs between universities and mines in Western Provinces and the Yukon and Northwest Territories are extremely high and need examination for separate funding.

In conclusion, I worked closely with the Chamber of Mines organization in South Africa whilst working for Anglo American Corporation's Technical Development Services. TDS had considerably more impact than COM in the successful introduction of innovative drilling, boring and materials transport methods. The rockcutter and narrower stoping width projects run by the Chamber are now a distant and expensive memory; unfortunately, at the time they stifled other engineers who had unorthodox ideas. I remember the horror when a suggestion was made to open up the stope width to permit mechanized loading to be used. Today the new O.F.S. mines are doing just that. We must avoid creating an organization which would stifle creative thought. In contrast, the Association of Mine Managers of S. Africa publish very frank and open papers on their methods and mistakes. Frequent visits to other mines are arranged for members with accompanying technical presentations. Control of the organization is limited to full members who must hold senior managerial positions on a mine, head office personnel and others are associate members only. I believe that establishment of a similar organization in Canada to guide the industry would be advantageous.

Mining and Mineral Process Engineering
Mining Research Projects
October 15, 1986

Title of Project	Researcher	Supervisor	Sponsor
Numerical Methods in Underground Mine Design	C. Soto MASc	C. Brawner	Sc Council of BC
Pillar Strengthening	J. Ringwald	C. Brawner	Sc Council of BC
Coal Blending Computer Model for Improving Mine Planning	E. Bauer MASc	A. Hall	NSERC
Ventilation Modelling	D. Mchaina PhD	A. Hall	No Grant
Recirculation of Mine Ventilation to Minimize Heating Costs	J. Saindon MASc	A. Hall	Ruttan Mine CANMET
Diesel Exhaust Cleaning in Underground Mines	G. Swiatek MASc	A. Hall	Diesel Controls Ltd.
Tunnel Simulation Using Micro Computers	D.R. Grant MASc	H. Miller	Science Council of BC
Optimum Stope Span Dimensions for Ruttan Mine	R. Pakalnis	H. Miller	Sherritt Gordon Mines
Investigation of Underground Mine Pillar Design Procedures	Y. Potvin PhD	H. Miller	Noranda Mines
In-pit Crushing and Conveying	J. Radlowski MASc	H. Miller	NIL
Underground Rock Mechanics Investigation at Aggasiz Mine	J. Rotzien MASc	H. Miller	Sherritt Gordon Mines
Rock Mechanics at Ruttan Mine	G. Silva MASc	H. Miller	Sherritt Gordon Mines
Development of a Rock Mechanics Model for Potash	M. SToakes MASc	H. Miller	NIL
Shear Failures During Rockbursting	D. Zou MEng	H. Miller	NIL
Universal Kriging Applied to Mineral Commodity Price Forecasting	R. Faulkner MASc	A. Reed	NIL
Ore Reserves at the Venus Mine, Carcross, YT	T. Stubens MASc	A. Reed	United Reno Hill Mines
Cone Penetration Test Parameters to Evaluate the Stability of Sand Tailings Impoundments	D. Woeller MASc	A. Reed	NIL

VIEWS AND OPINIONS OF MANUFACTURERS AND CONSULTANTS

THE ROLE OF CONSULTING ENGINEERS IN MINING AUTOMATION

L.M. Borowski, *P.Eng. and* **E.C. Card,** *P.Eng*
Wardrop Engineering Consultants

Competition from other countries is making it increasingly difficult for Canadian resource industries to sell their products. It is clearly evident that if Canada's mining industry is to maintain a satisfactory market share, the cost of production must be reduced. Although considerable strides have been made in efficiency improvement, more has to be done. Increased efforts are required in the application of advanced technology to mine operations. The mining industry has to innovate and enhance operations as never before.

The objective of this meeting is for the various players in the mining industry, including mine operators, government agencies, equipment suppliers, consultants, and universities, to present ideas and discuss options as to the paths which should be followed in developing and advancing mining automation in Canada. I would like to concentrate on the engineering consultant's role in this initiative.

Wardrop sees the engineering consulting industry as playing an integral role in the development and application of automated systems and equipment for the mining industry in Canada. Our industry's expertise includes the ability to manage programs and individual projects through the full design schedule, from conceptual through detailed design, construction and commissioning. We envision a team approach of meshing the mining industry's familiarity and experience with the problems at hand, with our approach to problem solving and applicable experience gained elsewhere.

Consultants have substantial knowledge of the mining industry, having worked with mine operators for many years. In addition, we know automation technology. For example, Wardrop has provided service to the mining industry for twenty years. In addition, our staff has been involved in the development of the Space Shuttle Remote Manipulator System (CANADARM), and several remotely operated systems for the nuclear industry. As a result, we are able to objectively assess and implement a variety of new and existing systems and equipment, and match the requirements of the operators to the capabilities of suppliers.

The consulting industry offers the ability to apply knowledge gained from involvement in other industries. We are well placed to adapt and apply recent technological advances from other fields to the mining industry. Wardrop, for example, has significant experience in developing equipment for use in the nuclear and space industries where, by necessity, many operations are carried out automatically or remotely. As mentioned in the previous symposium, work is currently ongoing in the Canadian Nuclear Fuel Waste Management Program. To make the current waste disposal concept work, significant equipment development, similar to that required for increased mining automation will be required. The results of both programs should be shared. Wardrop, through extensive involvement in the Canadian Nuclear Waste Management Program, is well qualified to participate in the endeavour.

The consulting industry is not tied to specific suppliers. Therefore, we can offer impartial assessment of equipment from different suppliers and manufacturers. In instances where off-the-shelf equipment is not suitable, the consulting industry's design capabilities can be utilized in developing designs for prototype and working equipment, so that the specifications of the end user can be met. Upon completion of fabrication of these designs, consultants can also oversee the testing of equipment to ensure that it meets specifications. Wardrop offers this service, as do many other companies. We are also in the business of building "one-of-a-kind" equipment to handle a specific task.

Knowledge of mining industry requirements and of available technologies also affords the consulting industry the opportunity to service government agencies in assessment and determination of suitable paths for research and development. We are in a position to assess the capabilities of suppliers, as well as the requirements of mine operators, and mate the two. I site as an example some of Wardrop's recent involvement in Government-sponsored programs which include identification of alternative energy sources, and efficient utilization of this energy. We recently completed a study into the potential of hydrogen as a fuel for mine vehicles.

In addition to automating with the goal of improving efficiency, it is also important for the Mining Industry to keep in mind the importance of finding new uses and markets for their products. Because of the glut of mined products on the world market, and the apparent long-term nature of these circumstances, we see a need for all resource industries, mining included, to develop new uses for their products. With the present over-supply, the best way to enhance Canadian mining operations is to identify new uses and markets. Alcan, for instance, is putting an enormous amount of effort into creating new markets through the innovative development of new uses for aluminium. Engineering consultants can aid the mining industry in this endeavour.

In summary, given our knowledge of the requirements of mine operators, and the state of current technology, the consulting industry can contribute significantly to the development and advancement of mining automation in Canada. Our objective is to work for, and with, the mining industry in overcoming the current constraints to increase productivity and efficiency, as well as product marketing.

THE CASE FOR PARTICIPATION IN A U.S.-BASED CENTRE FOR INTERNATIONAL CO-OPERATION IN MINING INNOVATION, AND FOR THE CREATION OF A CANADIAN CENTRE FOR RESEARCH IN MINING AUTOMATION

Spar Aerospace Limited

Canada has been invited to participate, financially as well as intellectually, in a proposed U.S. centre for innovation in mining automation. Through its participation in the first (MIT) seminar on Innovative Mining, and from its industry contacts in the U.S., Spar has concluded that the predominant mining interest in the U.S. is coal. It is probable that the resources of the proposed U.S.-based centre, from wherever derived, will focus on the solution of coal-mining problems, and will pay little heed to the needs of other mining companies.

The thrust toward mining automation in Canada is led by the metals mining industry. In spite of the potential for automation which exists in the coal and soft rock sectors, there is little evidence of their participation in the current initiatives represented by the consultative workshops and the activities of the ad hoc committee.

If a centre for research is to be of value to its supporting industry, then Canadian support should reflect the needs of the hard rock (metals) mining industry. A Canadian centre, separate from the U.S.-based centre, offers the only workable solution.

Insofar as the U.S. centre and the Canadian centre will address different issues in mining, they will be more complementary than competitive.

There is a strong case for encouraging cooperation between the two centres to make the fullest use of resources. Some kind of reciprocal associate status is suggested to facilitate the sharing of information.

The ad hoc committee which was spawned at the first CANMET consultative workshop has expressed a willingness to serve as an industry advisory committee to the proposed Canadian (McGill-L'école Polytechnique) Centre for Mining Automation. Spar maintains close contact with Canadian universities, and already co-sponsors a teaching/research fellowship at McGill in the field of machine intelligence. It would certainly sanction an advisory committee such as that proposed, and would continue to serve on that committee as it completes its transition from an ad hoc group to a permanent entity.

The Centre for Research in Mining Automation in Canada must be driven by industry, even integrated with industry, if it is to produce results which will address the real needs of the mining industry. The role and the structure of its advisory committee is, therefore, vital to the success of the Centre. The committee must exert real influence over the Centre's programs and operations. There must be interlocks, preferably fiscal, to ensure that the activities of the Centre clearly reflect the priorities which are communicated to it by its advisory committee. The Centre and its advisory committee should work to achieve full intellectual partnership.

Proper constitution of the committee, i.e. a balanced representation from industry, not just mining companies, but the traditional equipment suppliers and the advanced technology companies, is also essential to ensure that the research is realistic, and is compatible with the abilities of industry to implement its output. The mining companies will for the most part dictate the direction of the research activity, i.e. will define the problems to be solved. The manufacturing sector, comprising both traditional machinery and advanced technology components, will gather the fruits of this research and, through its product development efforts, bake them into a pie for ultimate consumption by the mining community.

In conclusion, Spar endorses the creation of a Canadian Centre for Mining Automation. If properly integrated with industry through an industry advisory committee, it can serve as a focal point for communication between the several sectors of industry and government involved in the automation initiative. It can also serve as the vehicle to accelerate innovation by seeding new, mine specific products into the manufacturing infrastructure represented on its advisory committee.

APPLICATION OF EXPERT-SYSTEM TECHNOLOGY TO THE MINING INDUSTRY

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Interact Research and Development Corporation

The artificial intelligence division of Interact is engaged in basic and applied research on issues relevant to the development of the next generation of tools for knowledge engineering. We have had the opportunity to apply our expertise in building expert systems to problems posed by clients in the mining industry.

In this paper we would like to present our views on how the mining industry could approach the use of expert systems for the greatest benefit to the industry. In order to do that it is necessary to provide a brief discussion of artificial intelligence and expert systems for those that are not familiar with the technology, and also a brief presentation of an application of expert system technology to mining problems.

ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS

Artificial intelligence is a branch of computer science aimed at understanding intelligence by modelling it in computer programs. The results of this research will realize computer programs and systems that are much easier to use and much more useful than conventional programs and systems. This branch of computer science consists of several areas of research — expert systems (also known as knowledge-based systems), machine vision, natural language understanding, machine learning, planning, problem solving and intelligent databases. A great deal of excitement has been generated over this field as it promises to provide computers with the capability of doing tasks that usually require human intelligence and experience.

An expert system is a computer model of an expert's knowledge and experience in solving problems from his/her domain of expertise. Since expert systems incorporate knowledge, they are sometimes referred to as knowledge-based systems.

Expert system development involves representing knowledge symbolically in a computer system so that it can solve problems that normally require human attention and intelligence. Symbolic knowledge is the representation of choice because human beings are symbolic information processors, whether they are solving numeric or non-numeric problems. In building an expert system, the emphasis is on capturing non-numeric knowledge and reasoning methods that are not easily represented in traditional computing approaches. By capturing some of the expert's experience and problem-solving abilities, the expert system can preserve the expert's knowledge in an automated colleague as well as provide intelligent consultation and assistance to less experienced personnel.

Expertise is often in short supply, expensive and/or inaccessible. One's resident experts often move, retire or die taking with them years of accumulated experience. In addition, one's resident expert often spends a considerable portion of time answering colleagues' questions, time that could be spent performing the tasks inherent in the expert's domain of knowledge. Through expert systems it is possible to capture an expert's knowledge in the form of a knowledge-base. Once captured, the knowledge in the system can: 1) grow and expand as the expert's knowledge grows and expands; 2) be made accessible to many people simultaneously whereas one's resident expert may have too many demands to allow for consultation with or inquiry from colleagues and subordinates; 3) provide needed advice and consultation in small or remote areas that are unable to afford or attract expert level personnel; 4) be adapted for high-level, specialized training of students and personnel; and 5) clarify a domain of knowledge. (Since expert knowledge is often implicit in nature, the development of a knowledge-base often represents the first explicit representation of the domain knowledge.)

GPEX: AN EXPERT SYSTEM FOR GEOPHYSICS

GPEX was designed to emulate the reasoning applied by geophysicists and geologists to the interpretation of subsurface samples. The system is intended to be an automated assistant to the geologist by providing a geological and geophysical interpretation of the geophysical properties of a drillhole sample.

At present, what typically occurs in the mineral exploration industry is that the drilling program for evaluating a property is established on the basis of surface results. The location, number, and depth of drill holes is predetermined. With the GPEX system the geologist in the field (or the office) can receive additional, more accurate information based on subsurface samples in real time. GPEX allows the drilling program to be more adaptable, and thereby optimizes the likelihood of finding an ore body.

GPEX has several major components including a geophysical interpreter, designed and implemented as a rule-based expert system, and a geological interpreter, designed as a frame-based expert system.

GPEX Modules

The input interface receives raw data from the geophysical instruments and manages data conversion, including numerical to symbolic transformations.

The geophysical interpreter uses geophysical properties comparable to the magnetic and electromagnetic measurements in a surface survey. Conductance, induced polarization and resistivity, and magnetic susceptibility are measured on subsurface samples. This module provides conclusions about the presence and amount of sulphides, pyrhotite, magnetite, graphite and massive versus disseminated structure. It uses a forward chaining inference engine and a knowledge base represented as production rules. The inference engine controls the firing of rules. The knowledge base was built using our in-house automated knowledge acquisition system.

The geological interpreter represents and uses the knowledge that an exploration geologist would bring to bear on the results of the geophysical interpreter and on additional information from reflectance and gamma ray spectrometers. That is, it performs a geological interpretation of the geophysical properties of the samples. A frame-based expert system was designed to represent and evaluate information about geological environments, rocks, minerals, chemical composition, and alteration types. This module draws conclusions regarding alteration, genesis, rock type and ore type. Anomalies in the geophysical properties of the rock are identified, their location is recorded and they are interpreted in terms of possible ore.

The across samples module will integrate interpretations across individual samples and provides a profile of a single hole. This module will summarize the type and rate of changes occurring through depth.

The across holes module will integrate interpretations across each drillhole successively. The module will produce a three dimensional representation identifying the type, location, depth, and dip of a potential ore body.

AN APPROACH TO EXPERT SYSTEMS FOR THE MINING INDUSTRY

Expert systems have now realized a fair degree of commercial success. Numerous successful applications of this technology are in routine use in industry and government. The mining industry has utilized this technology and will no doubt continue to do so. At present, these systems can only be built by experienced knowledge engineers working with experts from the mining industry. This situation is not unique to mining applications, indeed all industry sectors are at the mercy of knowledge engineers for the development of expert system applications. It is our conviction that the mining industry will obtain maximal benefit from this technology only when collaborative efforts between mining personnel and expert system researchers are channeled toward the development of expert system tools for use by those in the mining industry without the need for the services of knowledge engineers and computer scientists.

The process of acquiring the knowledge of experts and coding it in a representation employed by expert systems is acknowledged as the bottleneck in the development of these systems. At present, this process involves the use of a knowledge engineer and a domain expert to jointly build a knowledge base. Knowledge engineers are still in short supply and their services are costly. As one can imagine, reducing the need for knowledge engineers could speed up the process of building knowledge bases for expert systems and cut down on the cost of their development. These savings, however, hinge on the development of systems that can carry out this knowledge acquisition process automatically without the current time commitment from the knowledge engineer. The field of artificial intelligence is now at the point where we can realistically think of building systems that can replace knowledge engineers.

It is our belief that expert system development environments should be tailored for applications in the mining industry. In the first place, not all areas of expertise are alike. For example, the interpretation of geophysical instrument readings is very different from job scheduling in a manufacturing plant. Because of the differences in areas of expertise, the expert systems that are developed for these different areas are also very different. In the second place, the method used for acquiring knowledge may only be appropriate for a certain class of related expertise. For an industry like mining it is our experience that there are problems that are amenable to expert system technology. If collaborative efforts between those in the mining industry and those in the expert system business can identify classes of problems that are conceptually related, then work can begin on the development of expert system tools for each of these problem classes. If the object of these efforts is to develop automated knowledge acquisition techniques for each of these problem classes, then the research activity will not only yield useable applications but will also yield tools that can be employed by those in the mining industry to solve their own problems that fall into the same class of problems that the system was designed to handle. A program of research along this line could expedite the proliferation of this technology in the mining industry. One consequence of this could be that the Canadian mining industry could move into the business of exporting mining expertise in the form of expert system knowledge bases and in the form of expert system development tools tailored to handle problems common to the industry.

COMMENTS ON AUTOMATION IN THE MINING INDUSTRY

D.J. Ballantyne,
Davis Engineering Limited

Considerable interest and automation development in the mining community already exists; however, these advances appear to be very application specific and cannot be generalized to encompass the overall mining industry.

An initial assessment as to where technological advances can be made in the mining industry was presented in the paper "High Tech Development Needs in the Canadian Mining Industry" prepared by the Mining Association of Canada. It is interesting to review that paper at this time and see that several of the ideas have been addressed. However, I fear that this paper reached a limited few in the high technology community and it is an appropriate time to readdress and possibly re-emphasize the proposed suggestions and disseminate it to more members involved in the high technology business. This hopefully will enhance interest and ultimately lead to the involvement of many more technological partners.

However, the mining indusltry should not be involved with automation for the sake of automating. There should be an overall principle objective that the industry should strive for, a cooperative objective that is realizable and economically feasible. One suggestion that was offered as a potential goal is that by the year 2000 there shall not be any men underground. This may be too optimistic but nevertheless a goal must be defined to give direction to those who are involved. This goal should be based on factors that improve safety, enhance productivity, increase market competitiveness, and enhance equipment maintainability and reliability.

One of the major concerns that affects all involved is the funding of this automation. A cooperative commitment from the government, the mining industry, the manufacturing industry, and the academic community must be established. On determining what this level of commitment must be, an analysis of the benefits to be gained from automation should be performed.

The costs recovered and eventual payback due to automated operations should be fully appreciated in order to justify and solicit the necessary financial support. In order to facilitate this operational analysis, a representative mine should be selected for a case study and members from MAC, CANMET, and CATA should meet to formulate a national automation directive.

To summarize, the following items must be addressed:

a) Formulate a national automation directive;

b) Update and re-issue the paper explaining the areas where high technology can be applied in the mining industry;

c) Perform an operational analysis on cost recoveries and paybacks that can be attributed to the incorporation of technological innovations;

d) Determine areas of source funding required for the implementation of automation principles.

As a consulting manufacturing firm, we are interested in these automation requirements of the mining industry as opportunities for new product development. We are convinced that technological advancement in the mining business will be quite beneficial to all involved and that the advantages gained both nationally and internationally will be very rewarding.

MINE ELECTRONICS: A DEFENCE-SYSTEM MANUFACTURER'S PERSPECTIVE

Daniel R. Perley
Corporate New Business Development
Computing Devices Company
Control Data Canada

INTRODUCTION

The recent past has seen a dramatic increase in interest in mining automation not only on the part of traditional mining equipment suppliers but also from a wide range of high technology companies. Computing Devices Company, one of the largest defence electronics contractors in Canada, has been actively involved creating devices and systems to solve problems in difficult and hostile military operating environments. The company is currently undertaking a range of commercial new business development activities, oriented largely toward infrastructure industries in Canada and elsewhere. These are based largely on our existing technological strengths; however, it is expected that development of new technologies will be a part of the process.

During the mid-1970's several reviews were made of the applicability of leaky coaxial cable technology to mining detection and communication uses. Although a range of discussions were held with mines and academia, no firm projects resulted. More recently, our corporate new business development unit has been identifying a number of sub-sectors within the mining industry where we believe we can make a positive contribution.

INITIAL OBSERVATIONS

It is clear that the importance of the mining sector in Canada demands attention to its overall technology base. It is also clear, however, that despite this admitted need the industry is not unanimous on:

- technology base assumptions
  - mechanization
  - automation
  - robitization
- degree of labour substitution desired
- need for a national policy on equipment suppliers
- the ideal model of high technology company behaviour.

There is an increasing consciousness within the industry of the need for consensus on these issues if we in Canada are to make a credible contribution, both at home and on a world scale, to the field of mining automation. Throughout this paper the term "mining automation" is used to describe any application of advanced technology devices, sub-systems or systems to mining plant and equipment.

It is evident that the Canadian mining equipment manufacturing sector faces intense competition, not only abroad but in its own home market. During the past few years, mineral prices have been depressed and this has greatly limited the capability of the Canadian mining industry not only to purchase existing equipment but also to encourage the development of new devices. Although we are unable to comment authoritatively on the state of the equipment manufacturing sector all indications are that, unless something is done, there will be increasing market penetration by foreign mining equipment suppliers in Canada. This means that even if an electronic device is developed and successfully mounted on a piece of mining equipment (such as a drill, scooptram or whatever) developed in Canada there is little ability to piggyback this device onto an exported version of the same machine. This immediately creates a situation of a 'fifth freedom' export environment. In other words, the situation of a Country A company adding devices to or integrating electronics with mining equipment manufactured in Country B and delivered to a mine operator in Country C. In such a situation the Canadian electronics company would face a considerable difficulty in overcoming a natural tendency in Scandinavia, West Germany or wherever to mount domestic electronics on the equipment exported to a third country.

Figure A summarizes our reaction to the current situation, as we understand it. Within Canada there is definite potential for collaboration, for pilot projects and for the development of a technology strategy. There may also be the possibility of establishing basic commonality (with respect to foundation suits of vehicle electronics) with other resource industries to lengthen production runs through inter-sectoral development partnerships. In the export environment it is necessary to establish consortia which will obviously involve foreign mining equipment manufacturers unless the current Canadian industrial strategy is changed. It is also necessary to establish credibility as a supplier in one's domestic market before venturing into serious export work. Finally, a comprehensive export/market strategy is a requirement if there is to be significant foreign market penetration. The export market for equipment developed for related resource sectors (other than mining) is uncertain at this time.

COMPUTING DEVICES — KEY TECHNOLOGY BASE CAPABILITY AREAS

Computing Devices has pioneered the development of the use of leaky coax for detection applications. This typically uses a pair of coaxial cables buried in soil to provide a form of "guided radar" for personnel intrusion or obstacle location and detection. When coupled to a VHF transceiver and signal processor this sensor provides a very high probability of detection and low false alarm rate.

The cable and electronics technology developed for these sensors has applications in other areas. This can include such diverse areas as obstacle detection, vehicle counting and landslide, railway grade crossing or airport surface vehicle detection. The cable also provides a non-contact, distributed antenna for wide bandwidth communication between mobile and fixed stations.

Typical applications include communications in mines, tunnels, subways and buildings where traditional line-of-sight communication is impossible due to physical barriers. Other applications are local communications where only short-ranges are desired. Typical of these are highway advisory radio bulletins, on train-to-track communications where more data than that available via transponders is desired.

ComDev has extensive research, design and manufacturing facilities to meet the specific user application.

The company has also developed a wide range of integrated CRT/panel displays, electro-luminescent displays of various sizes and integrated television/digital display systems. Our electro-luminescent displays are available in rugged bright/dark ambient readable formats capable of meeting and exceeding demanding military specifications. The company also has experience in the development of sensor data-processing equipment capable of operating in extremely hostile environments, as an integral part of complex systems. Current research and development projects cover a wide range of areas related both to our current activities and to new initiatives.

The company has an interest in autonomous/semi-autonomous vehicles, the development of which pose a wide range of technical and operational challenges. The definition of key requirements and priorities is essential to the specification of the system which will meet real world needs. There may be an opportunity for the development of generic resource sector vehicles based on a range of modular heavy duty chassis and carrying a basic or foundation suit of electronics. There could be standardization of on-board at a vehicle/surface protocols plus a range of modular options such as sensors, control equipment and interfaces, central processors, enhanced communications, manipulation systems, and so on. Key technologies in development of such vehicles would be environmental sensing, real time control processing and systems integration.

It may also be desirable to consider the development of trunk communications systems for mines which would integrate the existing communications and control systems and which would require a single prime contractor charged with overall turnkey responsibility. The development of component interchange ability, industry standards and an overall control/communications protocol for mining use is of real importance to such an effort. There may also be the need to do basic technology research on mining communication and detection systems — clearly no one has a 'perfect' answer at this time but a breakthrough is possible. Computing Devices has research capabilities, within its various operational units, in the following areas:

- detection
- signal processing
- flexible/smart communications systems
- development of equipment for rugged/hostile environments.

It is also noteworthy that there has been relatively little development in mine-warning systems in recent years. Such systems should not only communicate an alert but follow up with full warning information and possibly instructions. It should not necessarily be taken as a given that the means of alerting/warning miners of an unusual or emergency situation should be the same as the normal communication means. There is a considerable body of recent research, in Canada, on the development of advanced technology warning systems — some of this could be applied to mining needs. The clear pay-off in safety-oriented systems is in the lower accident rates with all of their direct economic benefits as well as indirect costs such as Workmen's Compensation Board premiums.

It may also be desirable to further develop electronics systems from the ground up, for large service vehicles used in open pit mining. To this point, most systems developed for these vehicles have merely been 'transplanted' from other vehicles or from non-vehicle environments. There are three key information environments which need to be brought together by such an integrated system:

— the operator

— the physical and operating condition of the vehicle

— overall mines/system operations including production optimization and economic issues.

The key components in the development of such systems include communications, sensors, processors and control interfaces.

CONCLUSIONS

There is a wide range of development possibilities within the Canadian mining industry. There is a need for Canada to decide which of the following three possible strategies it wishes to follow:

— use advanced technology development as a lever (along with other levers) to strengthen the Canadian mining equipment manufacturing sector, actively pursue collaborative development projects here and then penetrate export markets;

— develop and prove electronics capabilities here in Canada and then attempt to 'piggyback' such systems and devices onto foreign manufactured mining equipment sold to third party countries;

— forego mining electronics development entirely and import same from foreign countries.

The third option is obviously the least desirable and although the second option may offer lower costs in the short-term it offers much higher long-term costs. There would be no indigenous capability to develop systems for types of mines which do not represent a large enough world market to attract foreign attention. It is also difficult to believe that such a strategy would assist the Canadian mining equipment manufacturing sector even to maintain its current position. Finally, there would be a real challenge even to large and stable high technology firms in achieving worthwhile exports. To forego export potential is to greatly reduce the number of production units over which development costs must be amortized. Unless government and industry groups wish to front-fund most equipment-system development, it may be difficult to develop a business case for such efforts by Canadian companies.

The first option is therefore, by process of elimination, the most desirable one from a high technology industry point of view (at least this is our company's perspective), however it is also obviously the most challenging. It is up to the mining industry to evaluate whether the first option is also in its own long-term interests; however, we believe there are many arguments that this is the case. During the coming months it will be necessary to develop and discuss such strategy options in more detail to allow all 'stakeholders' to make firm plans.

Finally, it is necessary that within the individual relationships developed between high technology companies, mining equipment makers and mine operators there be an open and comprehensive statement of goals and objectives at the outset. Most high technology companies are interested in the development of applications based on proprietary or assured technologies but are not primarily interested in simply transferring those technologies. Conversely, virtually all end users for whom applications are developed are not in a position to accept, nurture and further develop given technologies simply because this is not their primary business or expertise area. A clear understanding of what each party brings to the table, and of mutual expectations, will result in the development of healthy long-term working relationships.

A Series of Slides Presented

Slide 1

Computing Devices Company
Commercial New Business Development
Mine Electronics
Prospective Activities/Corporate Interests Areas

Slide 2

Corporate New Business Development Effort

— mid to long range time horizon

— co-ordinate efforts at business unit level

— military and commercial elements

— build on existing technological strengths/products

— develop new (complementary) technologies

— indigenous focus

Slide 3

Commercial New Business Development

— Oriented towards infrastructure industry

— Concentration on specialized products

— Clearly identified current/pending requirement

— Potential for natural advantage

— Collaborative programs where warranted

Slide 4

Previous Mining Involvement

— Leaky coax technology reviews — mid 1970's

— New business development — 1986
- sub-sector potential identification
- review of requirements
- understand current technology base
- establish preliminary contacts

— Believe we can contribute

Slide 5

Initial Observations

— Importance of mining sector demands attention to technology base
— Industry not unanimous on:

- technology base assumptions — mechanization
  — automation
  — robotization
- degree of labour substitution desired
- need for a national policy on equipment supply
- ideal model of high tech company behaviour

— Industry increasingly conscious of need for consensus
— Canadian equipment manufacturing sector faces intense competition

- no piggyback potential
- 'fifth freedom' export environment (Country-A company integrating products of Country-B in a mine in Country-C)

Slide 5

Initial Reactions to Current Situation

— Generically there are four markets

	Canada	Export
Mining Sector	— collaboration — pilot projects — technology strategy	— consortia — credibility — export/market strategy
Related Resource Sectors	— commonality — inter-sectoral development partnership	— environment uncertain

Slide 6 and Slide 7

Computing Devices — Possible Relevance
Key Technology Base Capability Areas

— Limited RF communication technologies

- presence detection
- voice and data communications
- sensor head-end and/or support
- vehicle to infrastructure links

— Display systems

- electro-luminescent displays
- integrated CRT/panel displays

— Sensor data processing equipment

- highly demanding environments
- designed as integral part of system

- Artificial intelligence
  - expert systems
  - smart tactical systems — environmental learning
- Autonomous vehicle technologies
  - environmental sensing
  - real time control processing
  - systems integration
- Trunk communications systems
  - integrate existing communications and control systems
  - prime contractor approach required (one firm responsible)
  - component interchangeability — industry standards
  - need to do basic technology research (no one has answer but a breakthrough is possible)
  - research component capabilities of computing devices
    - detection
    - signal processing
    - flexible/smart communications systems
    - rugged/hostile environments

Slide 8 and Slide 9

Some Possible Areas of Development and Application

- Mine warning systems
  - communicate alert
  - miner may follow up via — warning system itself
    - normal communication system
    - other means
- Large surface vehicle electronics
  - aimed at very large vehicles wholly/partially mining unique
  - bring together three information environments
    - operator
    - vehicle health
    - mine/system operations (including economics)
- Components
  - communications
  - sensors
  - processors
  - control interfaces
- Autonomous/semi-autonomous vehicles
  - wide range of challenges
  - requirements definition/priorities are key
  - opportunity for generic resource sector vehicles
    - basic modular heavy duty vehicles
    - basic suit of electronics
    - on-board and vehicle/surface protocols
    - modular options:
      - sensors
      - control equipment/interface
      - processors
      - enhanced communications
      - manipulation systems

VIEWPOINT OF BLACKBOX CONTROLS LTD.

Blackbox Controls Ltd. is a Canadian designer and manufacturer of radio controls, automation and other specialized electronic systems for use on mobile machinery and in conjunction with machinery. Over half of our production is provided to the mining industry. Our specialization is turnkey system design, manufacture and installation for machinery manufacturers and mining companies. Our customers include such prestigious Canadian mines as Inco Ltd., Falconbridge, Kidd Creek Mines, Rio Algom, Noranda, Sherritt Gordon, and many others.

OVERVIEW OF AUTOMATION IN MINING

Electronics and automation can be implemented at a mine through two basic approaches: evolution or revolution. The revolutionary or all-at-once approach, requires either the virtual reconstruction of an existing mine or the opening of a new mine. In both cases, massive capital funding is required. This distruption of production and large scale funding is not usually available, and as a result, the most commonly practised approach is evolutionary or one-step-at-a-time. It is our hope to show that this step-by-step, small scale automation can be gradually expanded, as funds are available, into a large scale minewide automation system. In this way each step is justified by the savings it generates and the useful life of existing equipment is extended by retrofit of this automation.

The evolution of a minewide automation system can be seen as having two major phases.

Phase I includes the conversion of production and haulage machinery to an electronic interface for the initial purpose of radio control and simple onboard automation. It is our assumption that these Phase I systems will usually be retrofitted to existing machines or to machines of current but not advanced design.

Phase II More extensive automation including feedback loop sensors are added to the Phase I electronics to provide longer periods of unattended operation. The goal is to provide the ability for one man to operate two or more units. This phase includes the use of wireless inductive loop guideways and CCTV to provide semi-automated haulage for both tracked and trackless machines. Dedicated short runs of high speed data link for the CCTV needed to control Phase I machinery and for linking and multiplexing of work stations which require only intermittent operator attention will be integrated into the MWCS later.

PHASE I

Radio-Controlled LHD's

In 1978, Blackbox Controls and Jarvis Clark installed our first model LHD16 radio control on a scoop at Inco Metals in Sudbury, Ontario, Canada. This machine was used to recover shot ore left at the angle of repose in the bottom of blast hole stopes. Manned machines could not be used to recover this material as the operator could not be sent beyond the protection of the back. With the radio-controlled scoop the operator was able to send the unmanned machine into the dangerous area and recover this ore which was previously being abandoned in the backfilled stope.

The success of this early unit was a key element in the development of VCR bulk ore extraction techniques at Inco Metals. Today, over 100 radio control conversion kits have been installed on all sizes and makes of machines from one yard to eight yards. Installation is frequently provided on site by our installers, although many customers have the capability of completing their own installations. Radio scoops are being used with this system for various blast hole techniques, removal of pillars, many types of open stope recovery and, in one case, the disposal of radioactive waste. Early concerns about the operator's inability to see the machine adequately, his loss of machine "feel" by not being on the machine himself proved to be unfounded in actual practice. Machine performance and production does not suffer if the radio-controlled operation training periods are very short.

In most applications, the radio-controlled scoop is used alternately in radio mode and manual mode. The operator loads the machine in the open stope with the radio control and then switches to manual mode for tramming to the ore pass and dumping. In some larger stopes, the scoop stays in the blast hole on radio control to load trackless haulage dump trucks which are also equipped with radio control for placement near the scoop. Where the tramming distance is long, this would be the preferred method using the less expensive machine in the haulage portion.

Radio-Controlled Locomotives

Another Phase I application is the use of the Blackbox Model MLC 16 Radio Control on tracked haulage systems, including trolley locomotives, battery locomotives and diesel-powered, hydrostatic locomotives. The most frequent application is to allow one-man loading and unloading of the train. Manual loading and unloading operations require one man on the locomotive and a second man at the loading or unloading station to operate the stationary equipment. Radio-control conversion of the locomotive allows the man at the fixed station to operate the train without a helper. In some mines, two-man tramming with the train is necessary if the locomotive cannot be run around the train to travel in the opposite direction. Radio Control allows the operator to operate the train from the opposite end from the locomotive without a second man.

Radio-Controlled Drills

The equipment currently being subjected to much intensive development around the world, for the move to mine automation, are the various jumbo drills. Both the vertical down-the-hole type jumbos and the horizontal boom type jumbos require the operator to spend much time at the work face in order to set the machine up, change drill rods and bits and make fine adjustments. The conversion to radio control at the Phase I level as a retrofit of existing machines provides productivity improvement and considerable operator convenience as he sets up the machine. Less expensive umbilical controls can achieve these same results, however. The major advantage in converting to radio control as an initial step is that it provides the electronic interface which is necessary to achieve the limited automation available in Phase II.

Other Phase I Controls

Hydraulic Booms such as those manufactured by Teledyne fitted with hydraulic hammers are used extensively in mining for the reduction of oversize ore at the crusher grizzley. Most of these applications require the continuous stationing of a man in a control booth to watch the crusher feed and prevent this jamming problem from occurring. As the operator's action is only required when a jam occurs, it is possible to handle this job from a remote location by using electronics and CCTV cameras. At the Phase II level this multiplexing of these crusher booms to one station will effect substantial manpower savings.

Scalers

With the advent of large blasthole stopes, the use of mobile scalers by remote control will be required in some specific applications. The wide variety of scaling equipment available makes generalization of the appropriate control difficult. Our slides show the use of radio control on a hydraulic truck mounted crane as used in the building supply industry where pinpoint accuracy of the 40-foot boom is essential. The conversion of most scaling machines would have to be considered as a 'one-of' custom application. However, the advantages of a wireless operation would make these machines versatile and convenient.

Trucks

At International Nickel, many trackless haulage trucks have been converted to utilize the same radio control as is normally applied to the LHD machines. This allows loading of trucks in the blasthole in the same manner as they would be used in an open quarry operation. If the tramming part of the work cycle is long, this provides maximized utilization of the LHD equipment. Another variation of this technique could be the use of the new continuous mining machines as produced by CMS for loading into these trucks. As the miner advances into the open stope, both machines can be provided with a radio control system for operation by the truck operator from the safety of the back. This miner is one of the new generation machines being designed from scratch for ready adaption to electronics and automation.

Blackbox Controls offers an Automatic Transmission Control for optimizing gear change vs speed and inhibits transmission abuse, thus reducing maintenance costs.

PHASE II

Jumbo Drills

With the addition of feedback sensors for drill travel, drill speed and rate of drill travel and the addition of logic boards to utilize this information, the drill can be left unattended until a drill rod or bit requires changing. This level of automation will provide automatic withdrawal and shut off the machine at the end of the work cycle. Our sketch on the board indicates that one operator would reasonably be able to attend more than one machine, subject to the distance between machines and the particular local conditions.

We have moved from Phase I to Phase II on the drills through the addition of sensors and logic to achieve a longer unattended work cycle and an automatic stip in the event of on board problems. This frees the operator's time by eliminating the "monitoring" function.

LHDs

Returning to our initial scoop of LHD radio control application, the Phase II increase in productivity is achieved through the addition of closed circuit TV and the wireless inductive loop guideway for unmanned tramming and remote dumping. The wireless guideway operates much like a track, in that the machine follows a path determined by the attachment of an antenna to the roof of the tunnel. The pathway is coded to provide stopping points for machines to await remote dumping at the ore pass and to utilize a passing recess where loop type tramming is not feasible. The goal of this addition is to have two or more machines in the work cycle, still with a single operator. Controlled access tunnels are essential to avoid the expense of anticollision systems on board the machines. The short dedicated runs of high speed data link necessary for CCTV would later become part of the MWCS.

Locomotives

The simple train loading and unloading operation provided by Phase I radio-control conversion, can, with the addition of the wireless guideway in Phase II and the addition of CCTV, be remotely operated from a central station in the same way or even perhaps from the same station as the crusher hammers. The use of unmanned tramming, whether trackless or tracked, requires limited access or protected access tunnels for safe operation. In both the tracked and trackless tramming systems, the inductive loop antenna, which is very low cost and easy to install, has limited data capability. This provides some continuous remote control even on long curved runs without the installation of a high speed data network.

Closed circuit TV can be used in Phase II for the multiple operation of crusher booms and other equipment from a central underground monitoring station. The wired connections between the TV cameras and monitors and the machinery and the remote control console would use the same electronic coding and decoding techniques as utilized in the radio control system. These installations can be networked together on short sections of data link which would be incorporated into a larger scale minewide communication system.

As well as providing radio control and automatic transmission, Blackbox Controls is involved in conceptual studies and development of a driverless truck guidance system for open pit mining. This system requires no cables.

General Machine Automation

There are two major paths to machine automation:

1. Installation of artificial intelligence on the machine.
2. Linking the machine via a communication path to a central intelligence, which may include a man at a remote manipulator and/or a computer.

The choice of method or correct combination of methods will depend a great deal on the nature of the application. Factors will include the task, the machine, the nature of the mine, the overall system approach, and the mobility of this machine.

Whenever the task is fairly precise and well defined, it is likely that an artificial intelligence, be it local or remote, can be utilized to do the task faster and better than a direct man/machine interface.

Whenever the job is multi-tasked and more general in nature, with a certain amount of random variations, the man-controlled or man-aided approach is required. This may be from local line-of-sight remote control, distant remote manipulation at a console with a closed loop TV monitoring the use of automatic guideways, or a combination of all.

Remote operation offers the advantage of the unmanned machine, being able to work in unpleasant and hazardous environments. Many man hours previously wasted in getting ready to go underground and to and from work, can be put to productive work, particularily when the remote location is at the surface.

Remote Manipulator Station

Our last slide shows one version of a remote manipulator station which can be adapted to provide remote control of any mobile or fixed equipment. The display can of course be used to provide messages to operator, as well as displaying the remote TV images.

SOME EXAMPLES OF REMOTE SENSING AND MANIPULATING TECHNOLOGY PERTINENT TO AUTOMATED MINING: DEVELOPED AT THE CHALK RIVER NUCLEAR LABORATORIES

H. Licht *and* **R. Joynes**
Atomic Energy of Canada Limited

INTRODUCTION

Nuclear power plants have equipment in areas where the radiation fields are too high for people to work in for extended periods of time. These risk areas are prime sites for the application of remote systems. By investing heavily in high levels of automation and reliability, CANDU has achieved significant gains in plant availability. When problems have developed, specific remote systems have been made available to protect the workers and minimize outage time.

The net result has been that in international comparisons, Canadian reactors have consistently come out on top in several catagories:

— CANDU reactors continually dominate the top 10 list for performance.
— The electricity rates in Ontario are on average less than half of what they are in the USA and France, and less than ¼ of what they are in Japan.
— The government investment in CANDU research has been far less than comparable government expenditures in all other countries. Per kilowatt-hour generated, the research cost has only been 60% of that in the USA and 25% of that in Germany and France. The comparatively lean budget predisposed AECL to operate like an industrial R&D organization.

OUR PRODUCT

Our product is research and development. Our mandate ranges from the advancement of knowledge over the production of research equipment, to the supply of special equipment and services. AECL, being Canada's largest R&D organization, has the stability to afford long term commitments.

OUR RESOURCES

The work force at Chalk River is about 2100 with a professional staff of 450. The remoteness of the site necessitates that a large variety of disciplines, skills and support is at hand. Our strength for development and manufacture of remote systems is based on the following disciplines:

— electronic, electrical, mechanical design and manufacture
— control systems, computing, communications, data highways expertise
— nondestructive testing, quality assurance, reliability/maintainability assessment
— project management.

OUR EXPERTISE

AECL's expertise in mining, as I know, is in three fields:

— uranium mining
— the underground research laboratory
— contract work for HDRK.

To assess our performance for doing mining-related research, I would like to refer you to HDRK and to our laboratory at Whiteshell, Manitoba.

Our expertise in remote systems will be discussed now by focusing on AECL's Chalk River Nuclear Laboratory and, in particular, on the Components and Instrumentation Division.

Development of remote technology — sensing, communications, manipulation — is a recurring requirement. Remote manipulation is always accompanied by remote inspection mostly through television, ultrasonic testing, or eddy current testing. Examples of remote sensing are:

— leak detection by acoustic emission
— detection and locating defects in nuclear components like pressure tubes, pipes, and heat exchanger tubes
— locating pressure tube/calandria tube spacers.

Signals generated by these sensors are extremely feeble, and would be completely swamped by background noise, unless the sensing technology was highly developed and optimized.

Communicating low power sensor signals often over long distance requires skillful application of communication line theory; a major concern to us is the adequate suppression of electromagnetic interference from high power equipment in generating stations.

Examples of remote manipulation are:

- — glove box handling of radioactive fuel
- — remote replacement of pipe hangers in the Douglas Point Nuclear Generating Station
- — remote replacement of reactor fuel channel pipe joints.

Communications for remote manipulation is usually based on purpose built state-of-the-art communications systems. Also, two large local area communication networks have been developed here with many years of professional effort.

WHY WE WANT TO BE PARTNERS IN MINING AUTOMATIONS

Atomic Energy's funding by Government is being gradually cut back to half of its former level and the federal government has requested AECL to increase its support to the Canadian non-nuclear industry. The first step undertaken was a restructuring to make us more commercially oriented. The next step was to identify significant areas of medium- and long-term R&D demand in Canada. Here, the need for automated mining was recognized. We are now in the third phase in which we want to get to know the mining industry and to attract its R&D contracts. So far, we have done work on sensing loose rock, and we have put in a bid for automated surveying. We intend to further develop a good reputation within the mining community to eventually reach our goal of becoming your major R&D resource in remote systems.

VIEWS AND OPINIONS OF THE MINING INDUSTRY

MAC PRESENTATION TO CANMET'S CONSULTATIVE WORKSHOP

The Mining Association of Canada

The Mining Association of Canada (MAC) represents a broad spectrum of mining companies at the national level. Our membership ranges from the largest integrated mining companies to one of the smallest industrial mineral producers and several companies who are in the exploration and development stage. Our members operate huge mechanized base metal, precious metal, potash, coal and uranium mines, as well as small, narrow stope mines including those John Udd recently visited at Yellowknife. Our membership is further broadened by including representatives of the Provincial Mining Associations and Chamber of Mines as ex-officio members on our Board.

Canada's mines are disadvantaged by distance to markets, lack of infrastructure, high cost labour, and higher health, safety and environmental costs than our international competition. As our President, Walter Curlook, pointed out at lunch yesterday, we have survived by quicker application of technology and improved mining practices.

During the Symposium which preceded this workshop, frustration was evident among the high tech people who sensed an attitude of "show us what you've got and we'll see what we can do with it" on the part of the mining industry. They wanted clearly-defined goals toward which they could then work. The mining industry will come up with some preferred research goals very soon, but it may help to take a moment to give the history of the industry's attitude.

The major changes in mining have tended to be changes in the mining methods brought on by availability of new equipment. As an example, mining engineers in each Sudbury mine working to perfect stoping practices and ore pass developments found themselves in a totally new environment with the advent of the scooptram and ramp access. The industry will continue to look for some new tool to bring another unexpected revolution in the mining method, but meantime it would be great if Canada could take the lead in control technology, as mentioned during the Symposium, or in some other facet which may emerge as industry attempts to prioritize its research needs.

The Canadian mining industry will continue to support domestic and foreign technology developments. We would like to develop Canadian strength, such as control technology or the high tech software component of automated equipment, but must support free trade in all things.

MAC actions re technology:

1. Cooperated with CATA in sponsoring first meetings in Sudbury.
2. Advocated establishment of "centres of advanced technology".
3. Joined ad hoc committee on automation in mining.
4. Support McGill-École initiative re a centre of mine automation and robotics.
5. Forming a group to evaluate needs for technology development at behest of Banff conference and our Board.
6. Called on CIM to join MAC in a comprehensive enquiry into the state of mining and mineral technology in Canada.

These six points are expanded below:

1. Two years ago, CATA and MAC organized a series of joint meetings and field trips and then a Symposium, "Applications of Automation in Mining: Present and Future". The Symposium resulted in a priorized list of technology needs of the mining industry. Ties were begun between the high tech industry and the mining industry and these are being pursued. In fact, some high tech companies have chosen to become associates of the MAC.
2. MAC has advocated the establishment of "centres of advanced technology" at Canadian universities. These would be jointly funded by Canadian mining industry and by provincial and federal governments. (Description of the concept is appended.)
3. In parallel, C.G. Miller was invited to join the "Canadian Ad Hoc Committee on Automation in Mining", chaired by Jacques Nantel. This Committee was the outcome of the first CANMET/OCRMT Workshop (March 86). It has met several times and is the organizer of the current Sudbury Symposium on "Applications of Automation in Mining", etc. The MAC strongly supports the work of the ad hoc committee and is likely to encourage it in any form to which it may evolve.

4. The above concepts come together in a proposal for a Centre of Mine Automation and Robotics in Montreal. McGill and École Polytechnique are preparing a joint proposal. Nantel, Curlook, and Miller have met on various occasions with officials of both universities. The most recent meeting also involved Dr. Claude Drouin, Executive Director of the Quebec Metal Mining Association.

   Once the proposal is received from the universities, industry's task will be to generate funding for the research chairs, fellowships, etc. Some university funding is assured. The federal funding source (NSERC) is favourable to the concept.

5. A recent seminar at the Banff Centre called for the development of a National Mineral/Mining Technology Strategy to be led by MAC. The MAC Board of Directors similarly called on a group of industry executives to evaluate needs for technology development and develop a course of action for MAC.

   This group is specifically not to duplicate the work of the Ad hoc Committee mentioned above. The view is to be broader covering all aspects of mining technology at the national overview or strategy level.

6. In a recent speech to CIM District 6 Annual Meeting, George Miller called for a national, comprehensive enquiry into the state of mining and mineral technology in Canada. This would evaluate our progress relative to other countries. He invited CIM to accept this challenge and join MAC in leading the enquiry. CANMET and perhaps other government agencies such as NRC and MOSST would be invited to participate in and support this effort.

   From the foregoing, it will be evident that MAC feels that quick application of mining technology is essential to the maintenance of the Canadian mining industry. Secondly, although the mining industry must acquire the best technology from whatever source, it would be supportive of a Canadian technology initiative.

NORANDA'S STATEMENT

Jacques H. Nantel, *and* **G. Sauriol**
Noranda Research Centre

At the First Consultative Workshop, held March 12, 1986, in Sudbury, Ontario, Noranda made a submission which addressed the desirability of increasing the degree of automation in mining operations. It was stressed that the ultimate goal of mining automation was to be able to operate all mining equipment from surface. It was further stressed that to achieve this important landmark, two important ingredients were needed:

i) high availability of equipment, and

ii) reliable, multi-function underground communication systems capable of linking all aspects of the mine to surface through voice, data, and image transmission.

We also believe that to implement a program of mine automation in Canada, the mining industry and all interested players need to develop a model for moving quickly. An organization should be created to accomplish the following:

i) transfer the existing know-how,

ii) bring the specialists from various disciplines together,

iii) generate new knowledge through research for future applications.

The formation of a Mining Automation Centre at McGill-École Polytechnique in Montreal, should be a concrete first step to achieve these goals and Noranda will support all efforts to establish a Centre devoted to Mining Automation in Canada.

Noranda also favourably views the establishment of Mine Automation Centres in the USA, but it has indicated that for the time being, it was not prepared to support these Centres with financial contributions.

Noranda thinks that Canada should collaborate actively with all efforts initiated in the USA.

Noranda fully agrees with others that the establishment of a Centre for Mining Automation in Canada should be industry-led. The inputs from the major mining organizations will come directly, and the smaller organizations should be represented through their Mining Associations.

Noranda sees a very strong and concrete role for CANMET and NRC in the support of mining automation in Canada. CANMET and NRC should work in a complementary manner in the areas of mining automation. Both should have strong programs and adequate funding that will permit them to carry out intramural research and also to be in a position to fund outside work. CANMET should more particularly devote special attention to the problems of the small mines in the area of mine automation.

All efforts by CANMET to marshall additional funds for mining research through the Mineral Development Agreements are applauded and Noranda recommends that CANMET continues to seek funding from this source vigorously.

Noranda senses that there is a strong interest on behalf of the hi-tech firms to become active with mining applications; Noranda views this favourably.

The establishment of the Ad Hoc Committee on Mining Automation is totally endorsed by Noranda. This Committee should be allowed to operate on this basis for a few years until an adequate permanent body could be organized to take over. Noranda recommends that CANMET participates strongly in the activities of the Committee.

The mining industry cannot look back and needs to embark into the automation era with a strong and coordinated program and CANMET should play a lead role in the implementation of such a program.

INCO COMMENT TO CANMET ON AUTOMATION AND ROBOTICS

J. Kelly
INCO Ltd.

It is difficult, if not impossible, to sustain productivity increases of fifteen percent per year on an ongoing basis by small evolutionary improvements. The competitive downward pressure on metal prices will continue and evolutionary gains will not compensate for the larger losses of lower metal prices. In order for mining companies to survive and be profitable, the imbalance between lower prices for products and small productivity gains must be corrected. There is considerable urgency to the problem.

If major improvements are to be accomplished, there must be radical changes to lower the unit cost of production. New solutions must be found to old problems. Automation and robotics research and development offers one such solution. However, the mining companies alone cannot solve this problem. There are three reasons why this is true. First, research and development must be completed quickly, which puts a strain on manpower requirements. Secondly, the required expertise is not readily available to most mining companies. Thirdly, if the development is left only to a few companies, the ultimate products of the technology will become very expensive to purchase.

It seems there is no question that the technology must be pursued. The immediate problem is how this should occur. There are individual companies involved in collaborative projects such as INCO and SPAR. There are contract research projects between CANMET and mining companies through Federal-Provincial Mineral Agreements, however these projects are mainly related to rock mechanics and ground control.

During the past year the profile of mining automation and robotics has been greatly elevated. The formation of an ad-hoc committee along with the proposal for a Centre for Robotics and Automation in conjunction with McGill and École Polytechnique offers a solution to bring together many of the individual research programs in a focused manner. All the major players in the game would come together in this initiative to confront the problem. Government, hi-tech companies, universities and mining companies would contribute to the initiative. Our company endorses the formation of such a centre. CANMET should endorse the initiative also. It has been suggested that CANMET lead the government initiative for some of the funding through future mineral development agreements with the provincial governments. The quality of the work presently being done under MDA is sufficiently good to serve as an example of the value for the dollars expended by government.

In summary, it is revolutionary change not evolutionary change that will keep Canadian mining leading in a very competitive business. The key to the future is a collaborative effort by all the major participants to focus on automation and robotics research through a centre of excellence.

POSITION OF HDRK MINING RESEARCH LTD. ON MINING AUTOMATION *(AS OF THIS DATE)*

M.E. Jowsey, *Director of Research,*
HDRK Mining Research Ltd.

This position is supplementary to the memorandum presented on March 12, 1986.

HDRK/MRL's mandate to engage in major, innovative, long range research and development has created problems when prioritizing programs.

The organization developed a strategic plan that would enable it to develop an order of priority to these programs. The strategic plan adapted by HDRK was to develop a continuous mining system. An initial emphasis is to be put on reducing the cyclical nature of mining as much as possible.

All facets of underground mining were to be part of a continuous system. This is not an evolutionary approach and it meant looking at very different and/or original methods.

A truly continuous mining system would be an automated system. The necessary mining methods need to be developed before they can be automated.

This approach has led us into other disciplines very different from the normal working domain of the mining engineer.

Each program we have tackled has involved as a first step finding out the state-of-the-art. This has turned out to be a time consuming and expensive exercise. Often we have discovered that there was nothing to develop, just buy it off the shelf. At other times absolutely nothing has been done in the field or it was so generalized it was useless. No matter how much suppliers of equipment or technology protest we have found no way to do it without a study. Some of these studies have been contracted out and some have been done with in-house personnel.

In the last four years some of the state-of-the-art reviews done were:

In-house study	1 year	$100,000
Contract	5 months	60,000
Contract	3 months	60,000
Contract	3 months	20,000
In-house	1 year	25,000

As we have gone into areas unfamiliar to the traditional miner, it has been difficult if not impossible to assess various suppliers or even find out what is available. Although these exercises are costly they have proved very necessary.

HDRK would like to see an organization developed that would allow easier access to what is available with a reliable product qualification system.

In the short term individual companies are the only ones that can assess their immediate automation needs, particularly as most of these are of a retrofit nature.

HDRK's individual shareholders are in competition in the market place and expect to stay that way. They banded together to do major work that they could not handle on their own, but nevertheless felt was necessary. The basic philosophy is that if it will get done in time without HDRK's involvement, let it.

I will close by repeating a paragraph from the March 12th memorandum.

Decisions relative to the direction of research and development get easier as more information is available. Our industry can ill afford the expense of re-invention. We might know where we want to go, but we need to know how far along the path we have come.

A VIEW ON APPLICATIONS OF AUTOMATION AND COMPUTERIZATION IN MINING

L.C. Gregg
Falconbridge Ltd.

Falconbridge Ltd. feels that the development of automation, computerization, or other associated technologies for implementation in the mining environment should target the following key areas.

i) Mining equipment automation and control;

ii) Sensors related to the monitoring of process, ground movement, and environmental parameters;

iii) Central control room ergonomics, e.g., operator interfaces and report formats;

iv) Distributed computerization for mines;

v) Data communication technologies;

vi) Minewide voice communication technologies;

vii) Video information communication technologies;

viii) Control elements related to the controlling of process, ground movement, and environmental parameters;

ix) Laser technologies;

x) Robotization.

The above technological areas have evolved effectively in the surface plants at the minesites over many years as well as in other areas of heavy industry. However, the underground applications are significantly more severe than the equivalent surface applications. Therefore, it will be necessary to carefully adapt existing technologies. Reliability and maintainability are equipment-related factors which must receive primary consideration. Well-documented designs which utilize simplicity and ruggedness as criteria are essential.

The objectives that automation and computerization technologies must evolve to meet within Falconbridge Ltd. include improved safety for the workforce, improved environmental conditions, the ability to operate production equipment remotely, and the ability to monitor and control the materials-handling process from a central location.

Recent experiences with the implementation of electronic systems within Falconbridge have shown that the most vulnerable part of the system is the component which directly interfaces with some area of the underground environment. This may be a human interface or a machine interface. It has also been found that to develop sensors and control elements is the most difficult task. The application of data communication systems and computerization is less difficult. Therefore, it is the recommendation of Falconbridge Ltd. that the electronic systems manufacturers, government agencies and educational institutions follow a stepwise process that emphasizes the careful development of human interface for mine operators, sensors for underground use and control elements. Subsequent to this work, the design and finalization of machine control systems should be carried out. At this point the application of robotization may be considered. However, the general feeling is that robotization will see limited use in the underground environment. Following these steps a more accelerated implementation of data communication technologies and computerization should be planned.

In summary, Falconbridge Ltd. sees the implementation of automation, computerization and associated technologies as being one of the most important paths toward improved productivity for the mining industry. However, a stepwise process of development beginning with sensor and control element design and ending with full automation and computerization is necessary.

COAL MINING ACTIVITIES

G. Zahary
Assistant Program Director
Research Program Office, CANMET

In CANMET, coal mining research is carried out by the Coal Research Laboratories (CRL) which have facilities in Devon, Alberta and Sydney, Nova Scotia. CRL maintains close working relationships with the Coal Association of Canada largely through its Coal Research and Development Committee and directly with industry. Although neither the industry nor the Association are represented at this workshop, work on mining automation is underway in the industry. The following two projects are being carried out by CRL on a cost-shared basis with industrial partners.

Evaluation of Truck Management Information System

Under contract the Philippi-Hagenbuch Inc. truck management information system is to be evaluated in a field trial at a western Canadian coal mine. The trial is to last about six months and is intended to:

— Evaluate the reliability, accuracy and utility of the system and its outputs.

— Assess the significance of outputs to productivity/costs.

— Identify problems and successes.

One of the features of this truck management system is that it is based on automated data gathering; the machine operator is not involved in developing the data base. This provides timely and normally the most accurate historical information base on which decisions are made.

The following basic information makes up the data base

— time
— haul cycle segments
— truck status
— loading equipment status
— vehicle location.

These data are manipulated and analyzed to perform the following functions:

— Make truck dispatch decisions
— Display the operating status of the pit
— Calculate and accumulate a variety of operating statistics.

(See: Hagenbuch L.G. "An Integrated Truck Management Information System (TRUCK MIS) Concept"; *Bull. CIM, August, 1986.*)

Operational Experience with the Conspec Environmental Monitoring System

The Conspec system is an environment, equipment-status monitoring system developed in Canada and widely used in U.S. coal mines. The unit being tested here has been modified to meet certification requirements for Canadian underground coal mines. Funding is available for a one-year trial to develop operational experience. Extra sensors have been obtained to closely monitor the production of methane in an operating longwall district. Manual measurements are being made to validate the information being obtained automatically.

MINING AUTOMATION

J. Scrimgeour
National Research Council

A considerable number of workshops and special studies in a number of different countries, Canada included, have all come to the same conclusion.

Mining automation is in a state of rapid advance, world wide. The beginnings of this in Canada are already evident in a very positive way.

Our principal task is to now ensure that we have in place the best possible plans and mechanisms for the management of this technological change.

This involves cooperation and collaboration, both domestically and internationally. The U.S.A. proposal to establish an international centre, which was discussed initially with other countries via the Joint Coordinating Forum for International Cooperation in Advanced Robotics (JCF/ARP), has been very helpful for showing us the need to develop a national Canadian plan and focus, as well as developing mechanisms for international collaboration. It lead directly to the holding of the first consultative workshop, the establishment of the ad-hoc committee on mining automation, to this seminar and to the second consultative workshop.

These studies and investigations have also shown us that in the case of mining, the technological change taking place, and the opportunity, is not robotics per se according to the usual definition of that word. Rather it is a wave of change, derived primarily from computer- and microelectronics-based sensing, communication and control capabilities. The best descriptive term is mining automation.

TECHNOLOGY STRUCTURE

The five principal elements, from a technology point of view are:

1. Mining and process knowledge
2. Equipment automation and control
3. New sensors and sensing techniques
4. Mine communication systems
5. Systems integration.

Organizational Structure

The knowledge and capability for these new mining automation systems, that is the sources of "know-how", reside in five types of organizations. This presents an opportunity for cooperation and collaboration, both within and between them.

1. Mining companies
2. Equipment suppliers
3. Consultants
4. Technology centres
5. University and government laboratories.

METHODS FOR COLLABORATION

The following mechanisms for cooperation and collaboration have been discussed and proposed by experts in Canada and elsewhere.

1. An information exchange network
2. Exchange of personnel and equipment
3. Joint site studies
4. Symposia and workshops
5. Joint project planning.

There is a real need for a well coordinated program. Individual mines cannot afford to each develop their own in-house solutions. Collaboration is needed so each does not develop a different wheel. Suppliers need advice from users and need to see a more unified market before they can undertake needed development work. University and government laboratories are anxious to participate, but also need direction, which could come from both mine operators and equipment suppliers. Everybody needs better knowledge of what is already available, what are the trends, and what are the opportunities.

The key question, therefore, is where does one start, and what is the next step. That is why we are here today to apply our collective intelligence to this question. Some of the answers may require some new organizational structures or mandates to make it happen.

Because things usually happen incrementally, one first undertaking might be to begin the documentation of a common system specification for automated equipment, sensing devices (both existing and needed), and mine communication systems. The formation of mine automation interest groups has been suggested, and would be a positive first step.

It will not happen all at once because there are many variations and views, and no one at this time can see the eventual total picture. However, if the process is started now, it may all happen just a little bit sooner, and with a little less total cost and effort in the end.

What we need to avoid, is having people working in isolation on the wrong solutions to the wrong problems.

MANUFACTURING INDUSTRY AUTOMATION

It is worthwhile to note that a parallel development in manufacturing industry automation, generally known as CAD/CAM, robotics or computer integrated manufacturing, has been proceeding for the past ten years. The mining industry therefore has the opportunity to draw from this, not only with respect to development of the technologies required, but also from a technology management and structural point of view.

In the latter sense in particular, the Ad Hoc Committee on Mining Automation is somewhat parallel to the Canadian CAD/CAM Council for the Advancement of Computer Integrated Manufacturing, and the mining industry centre proposed has similarities to the national centre for manufacturing technologies proposed by the CAD/CAM council in its 1980 and 1983 reports.

A description of the mission statement of the council, and a description of the proposed centre is given below. Recognizing that considerable effort over time has gone into these descriptions, this information may be useful to those planning parallel activities for the mining industry.

CANADIAN CAD/CAM COUNCIL

The Canadian CAD/CAM Council for the Advancement of Computer Integrated Manufacturing was established in 1978 by the then Department of Industry Trade and Commerce, and was known originally as the CAD/CAM Technology Advancement Council.

The Council, which has up to 18 members invited from industry, industry-related CAD/CAM Centres, educational institutions and government, operates under a broad mandate to provide advice to Canadian industry, educational institutions and government, and to promote liaison and constructive working relationships between the various interested parties. The secretariat and support for the council is provided by the federal Department of Regional Industrial Expansion.

Continuing on the basis of both past and planned activities, the mission statement is as follows:

> "To assist Canadian industry to enhance its domestic and international competitiveness by encouraging the creation of strategic initiatives that promote the effective and efficient use of advanced manufacturing technologies in design, development, production and marketing".

This can be accomplished by:

- — Providing appropriate advice to Canadian industry, education institutions and government;
- — Emphasizing the use of computer-based advanced manufacturing technologies;
- — Identifying on-going strategic issues;
- — Developing a national focus and philosophy;
- — Encouraging the participation of all parties, such as:
  - industry (users and suppliers)
  - labour
  - education and training
  - government

- technology centres
- financial groups
- technical societies
- industry associations.

— Disseminating reports and information;

— Monitoring international developments;

— Examining and encouraging the needs for human-resource planning and adjustment."

In addition to the *CAD/CAM Newsletter*, which is received monthly by close to 3000 persons, the Council has issued three major reports. The 1980 report in particular has had a major influence in establishing the Canadian infrastructure. The titles of these reports are as follows:

1980 — "Strategy for Survival"
1983 — "Closing the Gap"
1986 — "Management in Crisis: Implementing Computer-Integrated Manufacturing in Canada"

The secretariat services of the Council are provided by the Department of Regional Industrial Expansion as follows:

Secretariat
Canadian CAD/CAM Council
Office of Industrial Innovation, 5th Floor Centre
Department of Regional Industrial Expansion
235 Queen Street
Ottawa, Ontario
K1A 0H5

NATIONAL CENTRE OR FACILITY

The national centre or focal point which the Council hopes to see established in the near future would have four proposed functions. All four of these could be considered as useful and needed functions for the proposed centre for mining automation.

1. *Providing information and advice to industry*

   Since there are now approximately 75-80 individual CAD/CAM and Robotic centres established across Canada, it is expected that the national facility, in addition to its own resources, would primarily provide information and advice to Canadian industry on advanced manufacturing facilities by referring such requests to one or more of the existing centres, or by referral to the Canada Institute for Scientific Information (CISTI), which is part of NRC.

2. *Coordinating multi-firm development projects*

   This activity, similar to CAM-I in the USA or to the R&D activity of the Canadian Electric Association (CEA), would involve defining and coordinating technology development, diffusion and demonstration projects of common interest to a number of companies, on a shared-cost basis, at the request of industry, including arranging appropriate contracts for their development at appropriate locations.

3. *Coordinating activities between regional and other centres*

   Since there are approximately 75-80 existing CAD/CAM and Robotic centres, the coordination and sharing of information among them, on a voluntary basis, is expected to yield considerable benefit. An index and guide to these centres is available in reference 4.

4. *Providing a national and international perspective*

   In addition to the coordination role above, it is expected that the national facility should pay special attention to monitoring international developments in advanced manufacturing technologies. The national facility will therefore provide a national and international perspective to Canadian industry, community colleges, universities and other centres, on developments in advanced manufacturing, including the CAD/CAM field.

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2. "Mining Automation, Proceedings of a Workshop sponsored by CANMET/Mining Research Laboratories and the Ontario Centre for Resource Machinery Technology", Sudbury, March 12, 1986. *CANMET Special Publication* SP 86-6.

3. L. Nenonen, J. Scrimgeour, (National Research Council); J. Pathak, J.E. Udd, (CANMET), "Mining Automation Activities at NRC and CANMET", First Canadian Symposium on Automation in Mining, Sudbury, October 14-16, 1986. CANMET Mining Research Laboratories *Division Report* M&ET/MRL 86-100 (OP/J).

4. "A Reference Guide to CAD/CAM and Robotics Development and Information Centres in Canada and the U.S.A.".

   Available for $10, prepaid (English or French) from: NRC Publications, Ottawa, Ontario, K1A 0R6.

VIEWS OF GOVERNMENT ORGANIZATIONS

VIEWS FROM OTHER ORGANIZATIONS AND INDIVIDUALS

THE U.K. SCENE IN MINING AUTOMATION — A PERSONAL VIEW

J.B. Edwards
University of Sheffield

1. INTRODUCTION

The need for mine automation has been long recognized in the United Kingdom and the writer has been privileged to be associated with some aspects of its development during and since the early attemps of the coal mining industry to achieve the so-called Remotely Operated Longwall Face (ROLF) of the mid 1960's and early 1970's: efforts stimulated by NASA's success in flying manned rockets to the moon. The view of the U.K. scene presented here is necessarily a personal one and is based on an ongoing contact with the industry through R&D projects in the following areas:

(i) Longwall face automation: vertical steering-and load-control;

(ii) Materials handling: bunker and bunker-conveyor control;

(iii) Coal clearance: control by integrated large-scale systems;

(iv) Tunnelling: load, profile- and steering-control.

Educational spin-offs have included:

(i) Computer-based training, using simulators for operators, management, and technical staff in the areas above.

(ii) Case studies incorporated into U.G. and P.G. courses taught at Control Engineering.

(iii) Numerous Ph.D. projects.

The research has been funded by both NCB* and the Science and Engineering Research Council (SERC has supported a specially promoted programme in mining process development but focusing predominantly on the product separation and preparation end of the mining process rather than towards the pick-point). Much of the work at Sheffield University has been theoretical but sandwiched between field trials for data-gathering and the testing prototype control systems. Many of the lessons learned and ideas generated in these studies are now enjoying widespread exploitation in the field. Simulation has figured large as will become evident from the following brief review of the above-mentioned projects and activities.

2. APPLICATION DESCRIPTION AND PROGRESS

In this section and later discussion those aspects of the problem with which the writer's team at Sheffield have been preoccupied will naturally dominate the material presented. This is because these are the aspects on which the writer is most qualified to comment. Some attempt to place the multidisciplinary tasks in proper context will be made nevertheless. The supporting visual material on which this presentation relies heavily will also help clarify how and where the R&D effort has been concentrated.

2.1 Longwall face automation

First attempted on the ROLF faces, vertical steering to keep the shearer loader nicely between the coal-stone partings at roof and floor has long been a priority for face automation. From early systems (1) based on nucleonic backscatter gauges and simplistic hardware algorithms, ruggedised present-day systems (2) represented by MIDAS and System 70,000 have evolved using natural radiation sensors for the main feedback, tilt-transducers to aid face-advance stability and mechanical contacting roof-tracers to combat floor-lift beneath the armoured face conveyor (AFC). On-board microcomputer systems distributed between the functions of transducer data-analysis, man/machine interface, remote communication and control-algorithm execution are employed. By prior selection of the appropriate algorithm from library, the system can be prestructured to cope potentially with a variety of longwall operating sequences. These can involve unidirectional or bidirectional operation of either one or two single-ended ranging drum shearers (SERDS) or a bidirectional double-drum machine (DERDS) allowing simultaneous control of extraction as well as undulation-following.

Research at MRDE and Sheffield University has revealed ranging drum machines to be potentially highly unstable in their steering behaviour over repeated advances of the coal face unless due compensation to combat a variety of machine-delays and sensing-lags is effected in the control algorithm: necessitating extensive data-storage within the

*NCB: now British Coal

controlling microcomputer. Much from these findings is now incorporated within the MIDAS system but new problems continue to emerge. In particular, it is becoming clear from theory and underground observation, that with underplated conveyors (A.F.C.'s) some ranging drum machine geometries (ratios of drum-width, AFC-width, pick-to-pan distance, sumping-depth and c of g-location) may be fundamentally unsteerable and a return to old-fashioned roll-steering may be required in cases where unfavourable geometries are unavoidable. Another important aspect of coal-face automation is load-control whereby the speed to traverse of the shearer is manipulated by feedback to regulate the current- or power-consumption of the cutter-motor. As with the steering problem, much dynamic analysis, control system design and simulation has been conducted in this area and considerable wear-and- tear on cutter drives and transmissions can undoubtedly be avoided by eliminating the severe load oscillations that result from conventional simplistic electromechanical controllers by adopting properly designed sytems with dynamic compensation. The main outlet for this research is currently to be found in the tunnelling area however where machines are generally of a more prototype nature at present.

With the modern shearer we have thus realised a primitive robot adaptable to a range of longwall mining methods*. It has one or two ranging arms and it is mobile along a semi-flexible track (the AFC) whose trajectory it itself controls by steering action from cut to cut. It can 'feel' (through cutter power measurement) and can 'see', though dimly, its environment via radiation sensors. It is now acquiring a 'Braille' facility through sensitized picks in the rotating cutting drum: Through correlation techniques, the pick-force pattern can be compared with a prerecorded master signature of the seam stratification so allowing the present location of the drum, relative to the seam, to be determined and acted upon. Trials on mock-up headings of concrete and flyash have proved most encouraging revealing extremely fine detail within the slab structure. Field trials will determine the correlation time necessary in real coal seams and whether the delays inherent in radiation sensing can be improved upon.

2.2 Tunnelling Machine Control

Inspired by success and speed of application of road-headers and ripping machines, tunnelling machine development in the U.K. is favouring increasingly the boom-type machine of various sorts: horizontal-turret, vertical-turret, single-arm and double-jointed arm mechanisms (DJAM's), track- and/or anchor-mounted types. They naturally yield greater flexibility of operation than do fixed-diameter, full-face tunnel borers, in as much as the tunnel's cross-section profile can be freely controlled within a bounding envelope: always provided proper control action can be applied to the two drives simultaneously! It is becoming increasingly obvious that, in general, this may be beyond the capabilities of the human operator and that automatic profiling may be essential irrespective of whether the other machine functions are automated or not.

Proprietary laser-tracking systems for vertical and horizontal steering purposes are installed and limited profile-control programs can also be incorporated with some systems. Full appraisals are awaited but difficulty in keeping a laser-detector matrix of a practicably small area 'on-beam' is proving difficult, particularly in situations where the machine-body is moveable latterally (by design or otherwise) within the turned cross-section. Beam-finder, coordinate-corrector systems are under development. Again, as mentioned in Section 2,1, research has shown that some machine geometries may be unsteerable fundamentally, despite the quality of the control system per se.

The load-control problem can be severe due to the profound interaction of cutting and machine structural dynamics. Often the stiffness of cutting and the machine stiffness are of comparable magnitude necessitating carefully designed control compensation. The problem has proved particularly severe with horizontal-turret machines leading to frequent replacement of $100,000 cutter gear boxes and DJAM's may be even more sensitive. Research at Sheffield based on dynamic analysis and simulation has produced a stable controller however, successfully field tested with considerable improvement in cutter-load patterns and the suppression of the low-frequency surging characterizing crude controllers. Field trials have been confined to single-axis driving (e.g. a horizontal turret m/c cutting a circular trajectory or a vertical turret machine cutting a horizontal or vertical straight line centred-on, or radiating through the turret centre) so far. However, a combined load- and profile-control system with the same quality of load regulation, complete flexibility in the choice of reference profile and good tracking capabilities designed at Sheffield has now reached the surface-trial stage. Its design has been based on modern control theory for interacting systems and it uses a unique parametric representation of the reference trajectory inspired by manufacturing-robot technique. Details have been reported to the recent CMA-supported Symposium on Mining Automation here at Sudbury (3). On a broader front, this Workshop may be interested to know of a report entitled "A Feasibility Study of Advanced Robotics for Tunnelling" commisioned by the U.K. Government's Department of Trade and Industry (DTI) from the NCB's Technical Department. This will be summarized by Mr. D. Barham (4) at the Penn State Conference, October 26-29.

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*It is also being used as a loading device in so-called 'strata bunkers': disused roadways equipped with shearer and conveyor used for temporary coal storage below ground.

2.3 Coal Clearance and Handling

Very considerable progress has been made over the past decade in the comprehensive monitoring, at the mine surface, of the coal transportation network from coal face to pit bottom and automatic or supervisory closed loop control of winding (increasingly giving way to drift conveyors) has been established longer. The well-known MINOS system (5) developed by MRDE* embraces the central monitoring of not only coal flow and bunker levels through the mine but many other environmental functions also. Much progress in data transmission including multiplexed serial PCM and leaky feeder radio communication with personnel and vehicles has been involved. As regards control however, much less has been done to evaluate the benefits derivable from this central intelligence-gathering in the form of comprehensive control designed using the methods of optimal control theory and the theory of large-scale systems. Operations research techniques have been used to optimise bunker sizes and sitings using various general-purpose simulation packages (SIMBELT, SIMLOC etc.) over the years but these presuppose only local control strategies, i.e. local bunker measurements setting local feeder rates and switching on and off nearby conveyors. In addition it has been accepted that the transportation system must attempt to cope with whatever flow-rate the power-loaders happen to be producing at the time. Considerable progress on the local control of bunker conveyors and the aforementioned strata-bunker has been made but the design of "globally-optimal" control rules has been left largely to the university sector. It too has been somewhat unexcited by the problem, preferring to tackle other large-scale systems, such as power generation, water and natural gas networks, traffic control, etc.

The writer's team has addressed the problem of comprehensive coal clearance control and demonstrated that modern control theory, whilst complex in the initial design stage, can produce elegantly-simple control rules capable of easy interpretation in novel situations. To demonstrate these findings, a large-scale real-time simulator of a freely structured clearance network has been developed allowing the rapid comparison of alternative simplistic control rules with the comprehensively designed option and allowing degrees of manual intervention. Animation by mimic diagrams of coal flows, bunker fillings, machine positions, and temperatures is included.

3. EDUCATION AND TRAINING

3.1 The Intellectual Challenge of Mining System Dynamics and Control

It is essential that this subject area be developed as a major component of the Mining Engineering curriculum, both in Masters' programs and for undergraduate consumption in order to generate engineers and researchers with the talents necessary to bridge the gap between mining and control technologies. Only by this means is it possible to generate and maintain the necessary momentum towards mine automation. This applies in the U.K. today following the recent savage reduction in R&D by British Coal at MRDE which had fulfilled this role, in some measure, hitherto. In Canada the need is crucial. Having set up the necessary facilities, it will, even then, require probably two waves of undergraduates and Ph.D.'s (hopefully in parallel by recruitment of graduates from outside, high-tech disciplines) before a really noticeable impact can be achieved. Thereafter progress could be explosive provided the necessary critical mass of intellect, experience, and stimulating projects can be assembled.

It is fortunate that Mining System Dynamics and Control is indeed emerging, in the writer's experience, as a unified teachable subject rather than remaining a hotch-potch of isolated, barely-academic topics. Not merely robots, mining machines also *fly* like space-, air- and undersea-craft in roll, pitch and yaw (albeit over a long time scale) through the harsh underground environment. This environment is one which the machines themselves generate, in substantial part. This is a unique feature of mining systems but is amenable to mathematical modelling and hence capable of interfacing to existing control-design techniques and profound control theory. (For control theorists, the mining process presents a particularly novel challenge by virtue of its numerous cutting and transport delays connected in intricate networks and its repetitive yet random nature). The intellectual challenge of "flying through rock" is therefore more theoretically exciting than other forms of flying and, if properly presented, should attract the most lively minds into the area of mining automation.

Viewed as "robotics" the mining robotic problem is also unique. The loads to be *felt* are not merely heavy (as is well understood) but, because of the interconnected dynamics of cutting, boring, blasting and profiling, are subtler in many ways than loads manipulated in manufacturing. *Seeing* the operating environment in true "world coordinates" (essential for long term automation of excavation) is also special not only in terms of the type of *eyes* required by the robot but also in linking eye to hand in a long-term-stable manner, i.e., over the entire history of the drivage or excavation.

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*MRDE: the former Mining Research & Development Establishment but now incorporated into British Coal's Technical Dept.

3.2 Professional Recognition of Mining Automation Engineering

The unique education prerequisites of mining automation emphasized above must be worked up into a coherent teaching package comparable in status with respect to courses in, say, aeronautical or aerospace engineering. The package must become accredited by learned societies and industry for subsequent professional qualification of its graduates as Mining Automation Engineers. Only tentative efforts at achieving this goal in the U.K. have been undertaken so far but it must be an essential objective for Canada.

3.3 Industrial Training

Existing personnel: operators, engineers, and management also require familiarization with control techniques and, in the U.K., this process has been gathering momentum in recent years. No automation project is now planned unless accompanied by a training package and the development of Computer-Based Training (CBT) enjoys considerable priority in the industry's development program (6). This has survived notwithstanding the savage R&D cutback in other fields. Sheffield has been fortunate in its association with mining CBT for the past four or five years with its development of coal-face simulators (7) (resembling fight simulators in principle if not in quality of graphics). Several of these systems are now installed in Area training centres and a simulator per mine is the ultimate objective. Simulation, for product transport and clearance and for tunnelling machinery, all involving driver and designer participation, are under development and provide an essential focus for technical, managerial, and policy-making meetings as well as for operator training.

Although mining methods are very different here, the same need for simulation would seem to apply in Canada. I ne cyclic and 3-dimensional nature of hardrock mining should not pose undue difficulty, though enhanced computing and graphics power above normal P.C. capabilities will be necessary initially for prototypes.

4. DISCUSSION AND CONCLUSIONS

From the review in Section 3 of the mining systems with which the writer has been involved, and, from the experience of mining engineers generally, it is obvious that, for the achievement of automation proper, mining systems must be treated comprehensively. Otherwise, by automating in a piecemeal fashion, the bottleneck is merely shifted up and down the production chain. Load-control of the winning machine is obviously important, for example, but makes little sense if the transport system downstream is unable to cope with the excess of material produced under "easy" cutting or loading conditions. Likewise, load-control should not necessarily override properly-scheduled production rates from multiple sources. Another important conclusion is that plant design and control design should be treated simultaneously as a single exercise.

Human beings will make automation possible and those involved will require proper training, retraining and education. Properly structured postgraduate and undergraduate courses in Mining System Dynamics and Control are required for the production of the mining automation engineers of the future. The subject has a potentially strong intellectual appeal that could attract high quality students but due professional recognition of their discipline must be afforded by the Industry and Chartered Institutions. For training of industrial personnel at all levels, simulators have a crucial role to play as well as in plant and system design.

The Canadian mining industry should note the infrastructural role of the U.K.'s MRDE in providing a crucial interface between mining and high-tech manufacturers, European funding agencies, universities and the mines inspectorate with the mines themselves and mining problems generally, quite apart from its own considerable R&D contribution over more than 30 years. It is particularly saddening to witness the recent curtailment of these activities which casts doubts over the industry's long-term future.

Another disturbing observation for established mining countries is Japan's International Transfer of Industrial Technology (ITIT) program for funding collaborative research between Japan, one of the technically advanced countries and a developing country; presumably for the ultimate exploitation of the latter's natural resources at the expense of traditional producers. Funding amounting to 5 million Yen per year over three years per project is provided by the ITIT program. It is also interesting to note their novel approach to mining automation (8) based on intelligent, fast-moving, adaptable robots rather than merely adding electronics to long-established machinery.

For huge projects such as comprehensive mining automation to suceed, some clear-cut "high-objective" with widespread popular appeal is required: Witness the early NASA space-program's target of "a Man on the Moon by 1970", and Japan's concept of "the Fifth-Generation Computer". What objective might be appropriate for mining automation in Canada? "No man underground by the year 2000" perhaps, but with crucial qualification; "without loss of livelihood of anyone employed".

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CANMET/MRL

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DEUXIÈME COLLOQUE SUR L'AUTOMATISATION DE L'EXPLOITATION MINIÈRE

ORGANISÉ PAR LE CANMET/LRM

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APPENDIX 1

FIRST SYMPOSIUM ON APPLICATIONS OF AUTOMATION IN MINING — PRESENT AND FUTURE

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APPENDIX 3

APPENDIX 3

A COOPERATIVE APPROACH TO MINING INNOVATION

A Brief Presented to the PROVINCIAL MINES MINISTERS' CONFERENCE
by
WALTER CURLOOK, President
Banff, Alberta
September 16, 1986

HONOURABLE MINISTERS...

The Mining Association of Canada is grateful for your invitation to appear here today. Your annual Conference provides a useful opportunity for all those interested in the Canadian mining industry to meet and exchange views.

Before addressing the main subject of our Brief, *A Cooperative Approach to Mining Innovation*, we wish to thank Ministers for accepting a recommendation we made a year ago in Charlottetown. We suggested establishing a Working Group consisting of federal, provincial and industry officials to examine economic and tax-related issues. A special Task force has worked for the past year. It reported earlier this morning. We believe that some issues have been clarified — others require continuing effort. Working together has been a very positive experience. We urge Ministers to continue these efforts through the Task Force or some more permanent joint committee.

Turning now to the main subject, we have become more and more convinced that the prosperity, and indeed the continual survival of our industry depend on constant innovation. Our technology needs continuous improvement if we are to hold our place in the international battle of "competitiveness". No doubt other countries will eventually pick up any new technology we develop but that is no reason to stop developing it. On the contrary, our only hope is to keep a couple of jumps ahead by continuing to innovate.

This is a task for industry, governments, and the universities. We must work more effectively together, as those in some other countries are doing.

At present, we are not doing enough. Industry, governments, and universities are having a hard time organizing for cooperation. To get maximum benefit for our dollars and effort, and to speed up the process of innovation, will require closer coordination and cooperation.

The Mining Association of Canada has begun a series of discussions within industry, as well as with both senior levels of government and universities, to promote a coordinated approach to mineral industry innovation.

A schematic representation of an institutional structure is presented in Figure 1. First, there is a national board or institute named, for purposes of discussion, *The Canadian Institute of Advanced Mineral and Metal Technology (CIAMMT)*. This is not a brick-and-mortar institution, but rather a committee of eminent persons meeting several times a year. Its purpose would be to establish elements of national technology strategy in support of this sector. Membership would include representatives of industry, government, and universities, together with the Directors of several specialized technology Centres (described below). National research priorities would be established.

CIAMMT would have no direct granting authority. However, a granting agency such as NSERC would be expected to exercise its authority in line with priorities and strategies established by CIAMMT. Government laboratories, as well as a series of specialized Technology Centres, would be expected to direct their efforts along agreed lines.

The Technology Centres would all be established at one or more university locations. Each Centre would be affiliated with a host university for purposes of support and administration. A Technology Centre would normally be affiliated with one or more *additional* universities for purposes of sharing facilities, accreditation for research toward advanced degrees, and so on.

It is anticipated that the main source of funds for operation will be provided on a matching basis by government and industry. "Sponsors" are defined as both of these funding agencies plus the host and affiliated universities.

Each Centre would be governed by an independent Board of Directors representative of the Centre's sponsors, and responsible for operating policy and management. Each would have an advisory Council, consisting of knowledgeable researchers, to provide program advice and coordination. Quality of Director and staff will be critical to the success of each Centre.

This form of support and governance is modelled after that of the Centre for Resource Studies (CRS), a highly successful policy research institute located at Queen's University and sponsored by Energy, Mines and Resources Canada, Queen's University, and The Mining Association of Canada. CRS has demonstrated that a cooperative approach among three sponsors can result in timely, high-quality work, applied to significant and relevant problems. The independence of the university is not compromised, but the research is focused on the issues facing the industry.

Each Technology Centre would be regarded as a *national* centre of excellence. As such, work would be carried out at affiliated universities and at *other* universities, where appropriate, across the country. In this way, it would exercise a benign leadership and coordinating influence.

To be successful, this system will require the cooperation of agencies which are accustomed to autonomy. However, the partial surrender of autonomy can also yield enormous benefits to participating institutions:

- — the possibility of increased funding, especially from the industry
- — more effective, faster innovation in Canada
- — the opportunity for academics and government researchers to be associated with commercial application of their discoveries
- — much more efficient use of scarce financial and human resources.

We have another example in Canada, besides CRS, of cooperative research between several universities, the government and industry, and that is IREM-MERI, *Institut de Recherche en Exploration Minérale — Mineral Exploration Research Institute*. It was established in 1972 with a mandate to serve as a national centre of excellence in the field of mineral exploration research. It combines the resources of the geology and geological engineering departments of École Polytechnique, McGill University, and Université de Montréal, and serves as the facility through which these departments interface with government and industry. Representatives from the three universities, from the provincial and federal governments, and industries working in Quebec, sit on the Institute's Board of Directors. The work of the Institute could be enhanced by greater participation by industry. Also, the question arises as to whether its scope can be expanded beyond the province of Quebec. For this to happen will require the affiliation of other Canadian universities and industry from outside Quebec. This Institute rightfully falls under the caption *Centre(s) for Geochemical and Geophysical Exploration Technology.*

Another question, yet to be answered, is whether in certain disciplines there should be more than one Centre.

The MAC believes that Canada's situation calls for a cooperative approach to technology development and implementation. We are confident that battles over "turf" will be infrequent, brief, and minor. The intrinsic benefits speak for themselves. Initial discussions with the potential actors indicate that cooperation will be forthcoming in the broader interest of Canada.

We solicit your active support of this concept.

Figure 1

CANADIAN INSTITUTE OF ADVANCED MINERAL & METAL TECHNOLOGY