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ONTARIO CENTRE FOR RESOURCE MACHINERY TECHNOLOGY

MINING AUTOMATION

AUTOMATISATION DE L'EXPLOITATION MINIÈRE

PROCEEDINGS OF A WORKSHOP SPONSORED BY CANMET/MINING RESEARCH LABORATORIES AND THE ONTARIO CENTRE FOR RESOURCE MACHINERY TECHNOLOGY

PROCÈS-VERBAL D'UN COLLOQUE PARRAINÉ PAR CANMET/LABORATOIRES DE RECHERCHE MINIÈRE ET L'ONTARIO CENTRE FOR RESOURCE MACHINERY TECHNOLOGY

SP86-6

Canada

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Sudbury, Ontario
March 12, 1986

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FOREWORD

In 1985 a proposal was made for the formation of an "International Centre for Research Applied to Automated Mining and Tunneling" in the United States of America. CANMET, as the principal mining research delivery vehicle in Canada, was asked to prepare and present an official national response.

In doing so in November 1985, it was mentioned that there was no national consensus of the needs of the Canadian mining industry for technical innovation. Because of the size and diversity of the industry it is not possible to make simple statements which reflect its exact needs. Nonetheless, it was clear that an attempt had to be made to bring the stakeholders together and to define, at least in broad terms, the needs for research thrusts.

Accordingly, a consultative workshop with representatives of the mining and manufacturing industries, academic and government departments, was held in Sudbury, Ontario, on March 12, 1986. Sponsored jointly by the Mining Research Laboratories of CANMET and the Ontario Centre for Resource Machinery Technology, the intent was to try to obtain a national viewpoint on the needs for automation in the mining industry.

Unfortunately, even though 40 persons were present, it was not possible to state that the views obtained represented the collective opinions of the entire industry. Because of economic circumstances, some of the very important sectors were not represented in person (although some written contributions were received). Notably absent were representatives from coal, potash and iron mines, open pit mines, and quarries. It was, therefore, our conclusion that at least one or more additional workshops would be required to accomplish the task. Plans are now being developed for follow-up sessions.

This report contains all of the written submissions that were received in connection with the workshop. Regrettably, not all of those attending were able to make written submissions and the written record is less complete than had originally been hoped.

Nonetheless, the collection represents an important starting point in the quest for a national consensus. As co-sponsors we take pride in having been able to initiate the debate. It is to be hoped that progress in the definition of a position will continue rapidly.

John E. Udd
Director, Mining Research
Laboratories, CANMET

John C. Wilson
Director, Technology Development
Ontario Centre for Resource Machinery
Technology

AVANT-PROPOS

En 1985, une proposition a été mise de l'avant pour la création d'un centre international de recherche appliquée en vue de l'automatisation de l'exploitation minière et du percement de tunnels aux États-Unis. On a donc demandé au CANMET, à titre de principal organisme de recherche lié à l'exploitation minière au Canada, de préparer et de présenter une réponse nationale officielle.

Le CANMET s'est rendu compte, en novembre 1985, qu'il n'existait pas de consensus national quant aux besoins de l'industrie minière canadienne au plan des innovations techniques. Compte tenu de l'étendue et de la diversité de l'industrie, il n'était pas possible de faire des énoncés généraux reflétant ses besoins précis. Néanmoins, il était clair qu'il fallait tenter de réunir les principaux intéressés afin de tenter de définir, tout au moins de façon générale, les orientations de la recherche.

C'est ainsi qu'a eu lieu le 12 mars 1986, à Sudbury (Ontario), un colloque de consultation réunissant des représentants des secteurs minier et manufacturier, des universités et des gouvernements. Parrainé conjointement par les Laboratoires de recherche minière du CANMET et l'Ontario Centre for Resource Machinery Technology (OCRMT), son objectif était de tenter d'en arriver à une idée générale des besoins nationaux en ce qui a trait à l'automatisation dans l'industrie minière.

Malheureusement, malgré la présence des 40 participants, nous ne pouvons affirmer que les points de vue exprimés représentaient l'opinion de toute l'industrie. À cause de circonstances économiques, certains secteurs importants n'étaient pas directement représentés (bien qu'on ait reçu des présentations écrites); parmi les absences les plus marquantes, citons les représentants de l'exploitation du charbon, de la potasse, du fer, des mines à ciel ouvert et des carrières. Nous en avons donc conclu qu'il faudrait encore une ou plusieurs autres rencontres avant que nous puissions accomplir notre tâche. Nous préparons en ce moment les prochaines sessions.

Le présent compte rendu rassemble toutes les présentations écrites reçues parallèlement au colloque du 12 mars 1986. Malheureusement, tous les participants n'ont pas pu remettre de présentation écrite. Le dossier écrit est donc moins complet que nous ne l'avions d'abord espéré.

Malgré tout, ce document constitue un important point de départ vers un consensus national. En tant que co-parrains de l'événement, nous sommes fiers d'avoir réussi à amorcer le débat et nous espérons en arriver assez rapidement à la définition d'une position globale.

John E. Udd
Directeur, Laboratoires de
recherche minière, CANMET

John C. Wilson
Directeur, Développement technologique
Ontario Centre for Resource
Machinery Technology

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CANMET/MRL & OCRMT

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Northbury Hotel
Sudbury

March 12, 1986

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COLLOQUE SUR L'AUTOMATISATION DE L'EXPLOITATION MINIÈRE

ORGANISÉ PAR LE CANMET/LRM ET L'OCRMT

Hôtel Northbury
Sudbury

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CANMET/MRL AND OCRMT WORKSHOP ON MINING AUTOMATION

Minutes of the meeting

Sudbury, March 12, 1986

BACKGROUND

In November 1985, the National Science Foundation of the USA invited representatives of the Versailles Agreement countries to participate in the formation of an International Centre for Automation of Mining and Tunnelling at MIT, Cambridge, USA. Canada's position was prepared and read by Dr. J.E. Udd of CANMET/MRL. At the meeting, it was mentioned that there was at that time no Canadian consensus. Because of that, it had been decided to hold a consultative workshop in Canada to seek the consensus of the Canadian mining, hi-tech and equipment manufacturing industries, universities and the Government. The workshop, jointly sponsored by CANMET/MRL and OCRMT on 12 March, 1986, was the result of that decision.

MINUTES

The workshop was co-chaired by J. Wilson of OCRMT and J.E. Udd of CANMET/MRL.

J. Wilson called the meeting to order and asked the participants to introduce themselves.

J. Udd told the members the purpose of the workshop and read from his paper on a Canadian position vis-à-vis International Cooperation in Research Applied to Automated Mining and Tunnelling. He said that the Government people were present to listen to the views of the participants, who were drawn from a cross section of the mining and manufacturing industry, consultants, universities, and the Government across Canada. He also read a letter from the OMA written by Bruce Campbell, a telex from Blue Taylor of PCS Mining, and a memorandum from D.B. Stewart of the Coal Research Laboratories of CANMET, in which their views on the topic were expressed. Mr. Taylor emphasized that there are 47 automated miners in the Saskatchewan potash mines and that the cost of maintaining these is about $700,000/machine per year - i.e., about $33 million a year!

He then requested each participant to give a short talk to express their, or their company's, views and to submit it in writing, to be published in the proceedings in May/June 1986.

The consensus of the mine operators with respect to the USA proposal was overwhelmingly in favour of participation, but it was cautioned that the USA mining industry is very different from ours. It is, and will be, dominated by the coal mining sector. Mine automation is inevitable but Canada should have a strong base of its own.

John Kelly, of Inco, stressed the need for the development of robust sensors, and on-board microprocessors for on-line analysis and diagnosis of mine equipment performance. He said that the potential for world-wide sale of such equipment is very high. Cooperation from other sectors of the industry is required very soon, however - in months and not in years!

Most of the mine operators present agreed to his statements and stated that they would like to see step-wise progress toward full mine automation.

Amongst the mine operators, there were problems with the definitions and meanings of the words: automatic, automation and robotics. The high-tech people were of the opinion that it would not be meaningful to discuss the differences in meaning at the present. They stated that sensors are available, and that it is a question of a transfer of information to the mine operators and equipment manufacturers. They agreed that it is difficult to develop sensors to detect physical changes in underground or geotechnical attitudes.

It was stated that it is very important for mining engineers to start understanding, working, and communicating with persons outside their own disciplines. Improvement in machine utilization is an important concern with the mine operators. Another area that requires immediate attention is underground mine communication.

P. Pickerill of Spar said that they have spent between $50,000 - 100,000 to investigate opportunities in mining but that they still are not sure of the directions that should be taken. They need guidance from mine operators. It is a risky business and strong cooperation and commitment is needed from all sectors. He believed that mine operators, because of their size, are in a better position to assume risk than are high-tech companies. To produce a new system, or to improve an old one, should be a three-way cooperative project with mine operators, high-tech companies and equipment manufacturers.

J. Pathak of MRL said that most of the time the mining industry talks in generalities, which gives the high-tech companies no basis for design. The end users should lay down the specifics of a problem, the design goals and parameters for a system, and hand these over to a high-tech company. It would make their job much simpler and would achieve the objective sooner.

M. Scoble, of McGill, indicated that it is not necessarily equipment or automation that increases productivity. Other influential parameters such as management and incentive schemes should also be studied. He then gave a comparative summary of the mining industries of the United Kingdom, South Africa and Canada and indicated the trends in these countries. He also made the point that there should be representation by operators of smaller mines, and also soft rock and open pit mine operators.

D. Menard, Strategic Grants Officer of NSERC, elaborated to the members the role that her organization plays and how funding is allocated to different disciplines. She also gave guidance on making applications for NSERC grants.

John Wroe was an observer in the workshop representing D. Ramsey, MPP. He expressed the opinion that the Government of Ontario is involving itself more and more in the mining industry, and a Canadian Centre for Mine Automation/Robotics would appear to fit well with the aims of the Ontario Government.

SUMMARIES OF THE KEY POINTS FROM THE INDIVIDUAL PRESENTATIONS

J. Kelly, Inco

- He read a paper "How Mine Operators View Automation". He stressed the need for the development of robust sensors, and on-board microprocessors for on-line analysis and diagnosis of machine performance. He said the potential for worldwide sales of such equipment is very high. He looked for cooperation from other sectors of the industry very soon - in months, not in years.

R. Werden, Blackbox Controls Ltd.

- He expressed the view that the cost of development of robotic equipment is not known but could be very high. Canada should play a leading role in such development.

P. Pickerill, SPAR

- Spar has spent $50,000 - 100,000 to investigate the opportunities for applications of high-tech in the mining industry, but they have not obtained any consensus from operators on where they should invest their money. They need guidance from the industry and need to share the risks involved with this endeavor. They want to take an evolutionary step. Mr. Pickerill thought that Canada is more innovative than the USA in mine equipment design.

M.C.E. Kossatz, Inco

- We do not know the value of the product in the future, and therefore one cannot pre-evaluate risks.

D. Bray, Domtar

- There is a lack of proper definition of 'automatic', 'automation', and 'robotics'. The meanings of these words are becoming confused and need clear definition. He said that there is a strong need for sensors to be developed in order to detect the changes in physical conditions underground and geotechnical attitudes. Accurate drilling will reduce explosives costs, over-break and roof support. He stated that rotary drills are best for his purposes and there are funds available for development of robot drills.

J.P. Roszell, Jarvis-Clark

- They are interested in equipment for export. Automated drilling is being developed by Montabert and, therefore, they would prefer to develop a microprocessor-controlled drill.

M. Jowsey, HDRK

- Companies have their own priorities and set the R&D goals accordingly. The industry, in some cases, does not know what is available. There is a danger of reinventing the wheel. Duplication would be very expensive. The Colorado School of Mines is lobbying for the NSF proposal for the Innovative Mining Centre. The hardrock industry should try to free itself from the drill and blast cycle.

J. Udd, CANMET

- He asked the participants whether they would like to tap into and import technology to be developed at the proposed U.S. Centre or to develop their own. Development of advanced technology for coal mining seems to be the main aim in the United States, at present.

J. McCubbin, Martin, McCubbin & Assoc.

- In replying to Milt Jowsey, he said that mines in Canada are often so distant from each other that it is very difficult and expensive to exchange information.

E. Dudgeon, NRC

- There are a lot of sensors currently available and new ones are constantly being developed. There is a need for gathering this information.

R. Lepp, AECL

- We develop our own sensors because we work in hazardous conditions.

I. Barrie, ORC

- There is a very intense program of sensor development in the USA. Mine environments often pose very serious and varied problems but sensors can be adapted.

P. Pickerill, SPAR

- Many sensors are available, but the detection of geotechnical anomalies is a far more difficult problem.

J. Nantel/G. Sauriol, Noranda Research

- They emphasized the importance of mining engineers working with persons outside their own disciplines. They believe in a progressive approach to solving mine automation/robotics problems; ultimately with mine equipment being operated from the surface. They are not happy with machine avail- ability at present. Priority should be given to improve underground communications.

E. Jackson, International Submarine Engineering

- It takes a long time to find out what sensors are required, and there- after 5 years or so to develop them. Furthermore, if sensors break down once often the operator takes it out! It becomes very risky if operators do not cooperate and share the risks.

Y. Su, Falconbridge

- He expressed the view that there is difficulty in understanding what robots are. There should be a better and simpler definition of robot. He urged that the mining industry should use the term mechanization or automation and not robotic applications. CANMET should act as a clearing-house in this field. He questioned how Canadians could obtain information from the proposed R&D Centre in the USA without assisting in the funding of it?

P. Townsend, Denison

- He supported Bruce Campbell's letter (written on behalf of the Ontario Mining Association) and suggested that any development in this direction should be in small regular steps. He said that we are at the end of the automation step. Priority should be given to geotechnical and machine reliability sensors, but that grade sensors are equally important.

I. Barrie, ORC

- People should not be overly concerned with the definition of a robot. This is a high-risk, high-value business but the returns are also high. He said that it is possible to automate old equipment but that this could be very expensive. He cited an example of completely changing a GM plant to new technology at the cost of $400 million, and associated personnel training costs of $10 million. The advantage of this changeover was a drastic reduction of overheads. The introduction of new technology requires very heavy capital expenditure. If it does not work, it may be the end of the business!

M.C.E. Kossatz, Inco

- The real problem is to justify a new technology when an old one is working. Someone has to purchase it and prove it.

P. Boorman, RMS

- His firm specializes in remote control equipment. With supervisory control it will be necessary to give an artificially intelligent nature to a machine. He stressed that an evolutionary approach to the problem is required. A big priority will be to improve safety. He thought unmanned vehicles, linked to a main computer to keep track of all operations, have a future in mining. His firm does a lot of mock-up wooden models before an actual system is built. It is expensive but avoids many possible costly mistakes. Computer modelling does not pick up all of the intricacies of a machine.

E. Card, Wardrop

- Different industries have similarities in their problems and, therefore, cooperation should be encouraged. His firm is under contract to AECL in connection with a nuclear waste management program. Some by-products of their research will be useful to the mining industry, e.g., automated material handling systems and remote vehicle placements.

P. Grant/P. Pickerill, SPAR

- Spar's remote manipulator system represents 1/8 of their total business. It is only in the last year that they have become involved with improving productivity and safety in mining. They are collaborating with Inco on an automated machine for roof bolting and wire mesh placing. To date, they have spent about $80,000 to find out what directions to take and where the opportunities are in mining. Specific opportunities have still not been identified. They do not want to duplicate existing technology, and are of the opinion that risk sharing in this business is very important. Mine operators, because of their size, should take greater risks than manufacturers and high-tech companies. To produce a new system or to improve an old one should be a three-way cooperative project, and priorizing the funding should be done with the Government.

R. Lepp, AECL

- He is looking for cooperation between the nuclear and mining industries, because his firm has expertise in remote systems. They have developed equipment to remotely locate where pipes are leaking and to repair them there. Such pipes are located in the bowels of nuclear reactors. A one-day shut-down of these power plants costs $250,000 - 500,000. AECL are also data communications experts, which could be very useful in mining; e.g., FM communication of multiple data on a single cable.

J. McCubbin, Martin, McCubbin & Assoc.

- He believes in a stepwise process for mine automation. He thought that the mining industry would benefit from the development of a mining automation protocol. Mine communications highways could be developed by high-tech companies. All controls/automation in the mines should be tied together, and not work as individual systems.

P. Skillen, Instantel

- He asked if MAP protocol has been assessed for its applications in mines, and if there was any operator who would be willing to take a lead in this area?

C. Mayer, OCM

- He indicated that artificial intelligence and expert systems are becoming both practical and applicable. This should be kept in mind for applications in mining.

J.P. Roszell, Jarvis Clark

- In his opinion, the workshop had good aims and should be repeated often to maintain the momentum. He urged for a strong cooperation with the industry, with definitive goals.

M.C.E. Kossatz, Inco

- There are many R&D programs done in isolation. Every operator wants something different. The industry should be able to develop partnerships without the help of the Government.

J. Udd, CANMET

- USBM is very heavily involved with equipment development technology. Our view is that the role of the Government should be to act as a catalyst for the joint development of equipment by manufacturers and mine operators.

P. Pickerill, SPAR

- Often the people who are going to use the product are missing from meetings such as this.

W. Williamson, RSI

- All parties concerned with automation in the mines should be brought together. There must be a long-term commitment by them. The Canadian Manufacturing Association is dominated by all other industries, but there is no member from the mining industry.

E. Cinits, CART

- He spoke about the Paris and London meetings (May 1985) and regretted that Canadians had not taken any initiative to bring the International Centre for Innovative Mining Systems, or a similar organization, to Canada. He thought that it would be important to maintain linkages with any USA Centre. More workshops, like today's, should be held.

E. Dudgeon, NRC

- He spoke on the role of NRC and indicated that, on occasions, NRC interacts with the mining industry. NRC provides their specialized facilities on a cost-recovery basis. It plays a complementary role, and develops industry standards.

J. Pathak, CANMET

- He stressed the importance of hardware development as a means of reducing trade imbalance with Finland and Sweden - countries that have even smaller domestic markets than Canada. About 85 to 90% of their mining hardware production is exported. Canadians are very innovative in mining methods (VCR mining method), but this is not a commodity that can be exported. Also, it is not necessary to develop equipment to suit a mining system, it is more likely to be the other way around.

Most of the time, the mining industry talks in terms of generalities. This gives the high-tech companies no basis for design. The end users should lay down the specifics of a problem, design goals and parameters for a system, and then hand these over to a high-tech firm. It would make their job much simpler and the industry would achieve something sooner. Most of the time, we are just 'beating around the bush' regarding these problems.

D. Goldsack, LU

- The MIT conclusion was that the drill-and-blast cycle in mining is a thing of the past. He put forward his proposal - with backing from HDRK - for a continuous mining machine. He stressed that there is still a lack of understanding of how rocks are bonded and what parameters dictate cutability. Unless this is well understood, it will be difficult to design a continuous-mining machine for hardrock.

D. Ménard, NSERC

- Presenting the different portfolios under which NSERC provides funding, she said that there are now $300 million available for research. She gave details about NSERC, its organization, its function, and how to apply for grants.

M. Scoble, McGill

- It is not necessarily equipment or automation that always increases productivity. Other influential parameters, such as management and incentive schemes, should also be looked into. He then gave a comparative summary of the mining industries of the U.K., South Africa and Canada, and indicated the trends in these countries. He was also of the opinion that this group meeting at the workshop should have a representation from smaller mine operations, softrock mines and open pits.

J. Wroe, Exec. Asst. to MPP D. Ramsey

- He said that the Government of Ontario is intervening more in the mining industry. A Canadian Centre for Mine Automation/Robotics fits well with the aims of the Ontario Government.

DISCUSSION

At the end of the session, J. Udd asked the participants the following questions:

1. **How do you react to the U.S. Proposal? (to establish an International Centre for Research Applied to Automated Mining and Tunneling)**

The consensus of the participants was overwhelmingly in favour of support and cooperation with the U.S. Centre, but to refrain from funding. Milton Jowsey (HDRK) informed the meeting that Dr. Gantry, of the Colorado School of Mines, is lobbying strongly to have the Centre established in Colorado. He has made a formal proposal to the National Science Foundation in Washington, D.C., and has obtained the backing of six or seven large mining corporations, including a few from Canada. He said that there is $10 million at stake.

Some members were concerned that the U.S. Centre would be dominated by coal mining people/corporations and that the problems of hardrock mining might be sidetracked. It was said that the U.S. has virtually given up on hardrock mining.

It was estimated that, within 10 years, robotics will account for about 10% of mine automation. J. Nantel suggested that there should be a Canadian committee to represent the interests of the Canadian mining industry to the Centre. All comments, proposals or suggestions made by the participants were similar to those made by J. Udd in his 'Canadian Position Paper' submitted to the meeting called by the NSF for the above purpose at the MIT in November 1985.

2. What initiative do we want to take in Canada?

It was suggested that there should be an organization in Canada to bring mine operators, mine equipment manufacturers, universities, consultants, and the Government together to discuss the needs of the industry. There should be somebody in the 'driver's seat' to maintain interest.

M. Scoble, of McGill, suggested that there should be a follow-up meeting or conference on this topic soon to maintain the momentum. It was also suggested that the industry should prepare a 'wish list' with specifications, and circulate it to the interested parties.

3. Where do we start?

It was decided to form an Ad Hoc Committee on Automation in Mining with the following members: J. Nantel (Noranda Research, Chairman), J.P. Roszell (Jarvis Clark), P. Pickerill (SPAR), E. Jackson (International Submarine), I. Barrie (ORC), E. Cinits (CART), J. McCubbin (Martin, McCubbin & Assoc.), J. Kelly (Inco) and J. Pathak (CANMET/MRL). A meeting of the committee members should take place within 3 months.

4. What are our needs?

No suggestions were made regarding specific needs of the industry, but it was decided that the ad hoc committee should come up with some requirements.

J. Udd summed up the events of the day and adjourned the workshop, with a vote of thanks to J. Wilson and OCRMT for making the arrangements and providing the hospitality for the meeting.

COLLOQUE SUR L'AUTOMATISATION DE L'EXPLOITATION MINIÈRE

PARRAINÉ PAR LE CANMET/LRM ET L'OCRMT

Procès-verbal de la réunion

Sudbury, le 12 mars 1986

ANTÉCÉDENTS

En novembre 1985, la National Science Foundation des États-Unis a incité les représentants des pays signataires de l'Accord de Versailles à participer à la création d'un centre international pour l'automatisation de l'exploitation minière et du percement de tunnels, au MIT, à Cambridge (É.-U.). La position du Canada avait été préparée et exposée par M. J.E. Udd des LRM / CANMET. On a mentionné, à la réunion, qu'il n'existait pas de consensus canadien à cet égard; c'est pourquoi on a décidé de tenir un colloque de consultation au Canada, afin de connaître l'opinion des secteurs canadiens de l'exploitation minière, de la haute technologie et de la fabrication de matériel, des universités et des gouvernements. Le colloque du 12 mars 1986, parrainé conjointement par les CANMET / LRM et l'OCRMT, faisait suite à cette décision.

PROCÈS-VERBAL

Le colloque est co-parrainé par M. J. Wilson de l'OCRMT et M. J.E. Udd des LRM / CANMET.

Monsieur J. Wilson ouvre la séance et demande aux participants de se présenter.

Monsieur J. Udd expose l'objectif du colloque et lit des extraits de sa présentation sur la position canadienne à l'égard de la collaboration internationale en matière de recherche appliquée en vue de l'automatisation de l'exploitation minière et du percement de tunnels. Il ajoute que les délégués gouvernementaux assistent à la réunion pour connaître le point de vue des participants venus de divers secteurs de l'industrie minière et manufacturière, du milieu des experts-conseils, du milieu universitaire et des gouvernements, de toutes les régions du Canada. Il fait aussi lecture d'une lettre de M. Bruce Campbell de l'OMA, d'un télex de M. Blue Taylor de PCS Mining, et d'une note de M. D.B. Stewart des Laboratoires de recherche sur le charbon du CANMET. Dans son télex, M. Taylor fait remarquer qu'il y a actuellement 47 mines de potasse automatisées en Saskatchewan et que leur coût d'entretien est d'environ 700 000 $/machine par année, soit à peu près 33 millions de dollars par année!

Il demande ensuite aux participants d'exposer brièvement leur point de vue et celui de leur entreprise et de le présenter ensuite par écrit, afin qu'il soit publié dans le procès-verbal, en mai-juin 1986.

En général, les exploitants de mines sont en faveur de la participation au centre proposé par les États-Unis, mais font remarquer que l'industrie minière aux États-Unis est très différente de la nôtre. En effet, elle est, et demeurera, dominée par l'exploitation du charbon. L'automatisation est inévitable, mais le Canada devrait avoir une base solide qui lui est propre.

Monsieur John Kelly, d'Inco, fait état de la nécessité de mettre au point des détecteurs et des micro-processeurs intégrés pour une analyse directe et un diagnostic du rendement de l'équipement minier. Il indique que le potentiel des ventes à l'échelle mondiale de ce genre de matériel est énorme. Il faut cependant obtenir la collaboration des autres secteurs de l'industrie, et ce, très bientôt - c'est une question de mois et non pas d'années!

La plupart des exploitants de mines sont d'accord avec ses remarques. Ils aimeraient voir une progression par étape vers une automatisation complète de l'exploitation minière.

Les exploitants ne sont toutefois pas tous d'accord sur la définition et la signification des mots automatique, automatisation et robotique. Les membres du secteur de la haute technologie sont d'avis qu'il n'est pas essentiel de s'entendre sur les différences de sens pour le moment. Ils ajoutent qu'il existe déjà des détecteurs, mais que le problème en est un de transfert d'information aux exploitants et aux fabricants d'équipement. Ils conviennent qu'il est difficile de mettre au point des détecteurs pouvant déceler les changements physiques dans les dispositions sous-terraines ou géotechniques.

On mentionne qu'il est très important que les ingénieurs miniers commencent à mieux comprendre ceux qui ne font pas partie de leur discipline, à communiquer et à travailler avec eux. L'amélioration du temps d'utilisation des machines est un des points de préoccupation des exploitants. Un autre point, qui exige une attention immédiate, est celui des communications sous-terraines dans les mines.

Monsieur P. Pickerill, de Spar, fait remarquer que son entreprise a consacré de 50 000 à 100 000 $ à l'étude des possibilités dans le domaine de l'explotation minière, mais qu'elle n'est pas encore certaine des orientations à prendre. Il lui faudrait l'avis des exploitants miniers. Les risques dans ce domaine sont très élevés et le succès dépend de la collaboration et de l'engagement de tous les secteurs. À son avis, les exploitants miniers, à cause de leur nombre, sont dans une meilleure position pour assumer les risques que les entreprises de haute technologie. Produire un nouveau système ou même en améliorer un déjà existant est un projet qui exige la collaboration des trois secteurs, soit les exploitants miniers, les entreprises de haute technologie et les fabricants d'équipement.

Monsieur J. Pathak, des LRM, fait remarquer que la plupart du temps, l'industrie minière s'exprime en termes généraux, ce qui ne donne aux entreprises de haute technologie aucune base de travail. Les usagers devraient délimiter les caractéristiques d'un problème particulier, indiquer les objectifs et les paramètres d'un système, et transmettre ces données à une entreprise de haute technologie. Leur travail en serait ainsi de beaucoup simplifié et ils arriveraient à des résultats beaucoup plus rapidement.

Monsieur Scoble, de McGill, signale que l'équipement ou l'automatisation n'augmente pas nécessairement la productivité. Il y a d'autres facteurs en cause, tels la gestion et les programmes d'encouragement. Il fait ensuite un exposé comparatif de l'industrie minière du Royaume-Uni, de l'Afrique du Sud et du Canada, en indiquant les tendances dans ces trois pays. Il explique aussi que les exploitants de petites mines, de mines à ciel ouvert et de mines de roche tendre devraient aussi être représentés.

Madame D. Ménard, agent des subventions thématiques au CRSNG, expose aux délégués le rôle que joue son organisme et la façon dont les subventions sont accordées dans les différentes disciplines. Elle leur donne aussi des conseils sur la présentation des demandes de subvention au CRNSG.

Monsieur John Wroe assiste au colloque à titre d'observateur, représentant M. D. Ramesay, député provincial. Il est d'avis que le gouvernement de l'Ontario intervient davantage dans l'industrie minière et qu'un centre canadien pour l'automatisation et l'intégration de la robotique dans l'industrie minière cadrerait bien dans les objectifs du gouvernement de l'Ontario.

SOMMAIRE DES POINTS-CLÉS DES PRÉSENTATIONS INDIVIDUELLES

J. Kelly, Inco

- Il fait la lecture d'une présentation sur la position des exploitants de mines face à l'automatisation. Il fait ressortir la nécessité de mettre au point des détecteurs robustes et des microprocesseurs intégrés pour une analyse directe et un diagnostic du rendement des machines. Il ajoute que le potentiel des ventes mondiales de ce genre de matériel est très élevé. Il demande la collaboration des autres secteurs de l'industrie dans un bref délai - c'est une question de mois et non pas d'années.

R. Werden, Blackbox Controls Ltd.

- Il indique que le coût de la mise au point de ce matériel n'est pas encore connu mais pourrait être très élevé. Le Canada devrait jouer un rôle de chef de file dans ce domaine.

P. Pickerill, SPAR

- Spar a déjà consacré 50 000 à 100 000 $ à l'étude des possibilités d'application de haute technologie à l'industrie minière, mais n'a obtenu aucun consensus des exploitants quant à la meilleure façon d'investir son argent. L'entreprise a besoin que l'industrie lui donne des conseils et partage les risques inhérents. Elle est prête à aller de l'avant. De l'avis de M. Pickerill, le Canada fait davantage preuve d'innovation dans le domaine de la conception de l'équipement minier que les États-Unis.

E. Kossatz, Inco

- Nous ne connaissons pas la valeur du produit dans l'avenir; par conséquent, nous ne pouvons en évaluer les risques d'avance.

D. Bray, Domtar

- Il faudrait définir de façon appropriée les mots automatique, automatisation et robotique. On confond parfois leur signification. Il est important de mettre au point des détecteurs qui décèleraient les changements des conditions physiques dans les dispositions sous-terraines et la techniques. Une plus grande précision au niveau du forage permettrait de réduire les coûts des explosifs, les ruptures inutiles et le soutien de voûte. Les installations de forage rotary sont les meilleures pour les activités de son entreprise, et celle-ci dispose de fonds pour la mise au point des foreuses robots.

J.P. Roszell, Jarvis-Clark

- Son entreprise s'intéresse à l'équipement en vue de l'exportation. Montabert travaille à mettre au point des instruments de forage automatisés, de sorte qu'ils préfèrent concevoir une foreuse à microprocesseur.

M. Jowsey, HDRK

- Les entreprises ont leurs propres priorités et fixent les objectifs de recherche et de développement en conséquence. L'industrie, dans certains cas, n'est pas au courant de ce qui est à sa disposition. Il faut se garder de tenter de réinventer la roue. Faire double emploi, pourrait se révéler très coûteux. La Colorado School of Mines fait des représentations relativement à la proposition de centre d'innovation de la NSF. L'industrie de la roche dure devrait tenter de se libérer du cycle de forage et de dynamitage.

J. Udd, CANMET

- Il demande aux participants s'ils préféreraient puiser à la source du nouveau centre et exporter la technologie, ou mettre au point la leur. La mise au point de techniques perfectionnées d'exploitation du charbon semble le principal objectif aux États-Unis en ce moment.

J. McCubbin, Martin, McCubbin et Ass.

- Il répond à Mill Jowsey que les mines au Canada sont tellement éloignées les unes des autres qu'il est très difficile et onéreux d'échanger de l'information.

E. Dudgeon, CNR

- Il existe déjà des détecteurs de toutes sortes et d'autres sont en préparation. Il faut recueillir l'information nécessaire.

R. Lepp, EACL

- L'entreprise met au point ses propres détecteurs parce que le travail est effectué dans des conditions dangereuses.

I. Barrie, ORC

- Il existe un important programme pour la mise au point des détecteurs aux États-Unis. L'environnement des mines pose un problème, mais les détecteurs peuvent y être adaptés.

P. Pickerill, SPAR

- Il y a de nombreux détecteurs sur le marché; mais la détection des anomalies géotechniques est un problème beaucoup plus difficile.

J. Nantel/G. Sauriol, Recherche Noranda

- Ils font ressortir l'importance pour les ingénieurs miniers de travailler avec les groupes en dehors de leur discipline. Ils croient à une évolution progressive vers la solution des problèmes de la robotique et de l'automatisation dans le domaine de l'exploitation minière; à la limite, l'équipement pourrait même être commandé de la surface. Ils ne sont pas très satisfaits de la machinerie existante et croient que la priorité devrait être accordée à l'amélioration de la productivité de même qu'aux communications souterraines.

E. Jackson, International Submarine Engineering

- Il faut beaucoup de temps pour déterminer le genre de détecteurs requis et cinq ans ensuite pour les mettre au point. En outre s'ils cessent de fonctionner, l'exploitant les met de côté. C'est une entreprise à risques élevés si les exploitants ne collaborent pas et ne partagent pas les risques.

Y. Su, Falconbridge

- Il est difficile de comprendre ce qu'est un robot. Il devrait y avoir une définition plus simple et plus claire des robots. Il demande à l'industrie minière d'utiliser les mots mécanisation ou automatisation, plutôt que de parler d'applications de la robotique. Le CANMET devrait jouer un rôle central dans ce cas. Il se demande comment nous pourrions songer à demander de l'information au Centre proposé aux États-Unis, sans le financer?

P. Townsend, Denison

- Il est d'accord avec la lettre de Bruce Campbell (rédigée au nom de l'Ontario Mining Association) et propose que toute progression en ce sens se fasse par petites étapes. Nous sommes à la fin de l'étape de l'automatisation. La priorité devrait être accordée aux détecteurs géotechniques et de fonctionnement des machines, mais les détecteurs de teneur du minerai sont aussi importants.

I. Barrie, ORC

- Il ne faut pas trop se préoccuper de la définition du robot. Il s'agit d'une entreprise à risques élevés, à grand capital, mais le rendement est aussi très élevé. Il est possible, mais toutefois très coûteux, d'automatiser le vieil équipement. Il donne l'exemple d'une usine de GM qui a été tout à fait renouvelée, à la fine pointe de la technologie: le changement a coûté 400 millions de dollars et les frais connexes de formation du personnel ont été de 10 millions de dollars. L'avantage cependant a été une réduction radicale des frais généraux. L'introduction de la nouvelle technologie exige de grandes dépenses d'immobilisation. Si ça ne devait pas fonctionner, ce pourrait être la fin de l'entreprise.

E. Kossatz, Inco

- Le véritable problème est surtout de justifier une nouvelle technologie quand l'ancienne fonctionne toujours. Quelqu'un doit en faire l'achat et la preuve.

P. Boorman, RMS

- Son entreprise est spécialisée dans l'équipement télécommandé. Avec supervision seulement, il sera nécessaire de donner à une machine une intelligence artificielle. Il insiste toutefois sur la nécessité de procéder graduellement. Une des priorités sera d'améliorer la sécurité. À son avis, les véhicules télécommandés reliés à un ordinateur central, pour surveiller toutes les activités, pourront être utilisés à l'avenir dans le domaine de l'exploitation minière. Son entreprise fait beaucoup de modèles en bois avant de construire le système réel. C'est une méthode onéreuse, mais elle permet d'éviter bien des erreurs coûteuses. La modélisation par ordinateur ne tient pas toujours compte de toutes les complexités d'une machine.

E. Card, Wardrop

- Des secteurs différents ont parfois des points en commun; il faudrait donc encourager davantage la collaboration. Son entreprise travaille à contrat pour EACL, dans le cadre d'un programme de gestion des déchets nucléaires. Certains résultats de cette recherche pourraient être utiles à l'industrie minière, soit les sytèmes automatisés de manutention du matériel et la localisation des véhicules à distance.

P. Grant/P. Pickerill, SPAR

- Le système de manipulation à distance de SPAR représente 1/8 des activités de l'entreprise. Ce n'est qu'au cours de la dernière année qu'ils ont commencé à travailler à l'amélioration de la productivité et de la sécurité dans l'industrie minière. Ils collaborent avec l'Inco à un système automatisé de boulonnage de voûte et de mise en place de grillages métalliques. Jusqu'à maintenant, ils ont investi 80 000 $ pour savoir dans quelle direction s'orienter et quelles sont les possibilités dans le domaine de l'exploitation minière. Les avantages précis n'ont pas encore été déterminés. Ils ne tiennent pas à reproduire la technologie déjà existante, et sont convaincus de l'importance du partage des risques dans ce domaine. Les exploitants miniers, à cause de leur importance, devraient prendre plus de risques que les fabricants et les entreprises de haute technologie. Produire un nouveau système ou en améliorer un ancien devrait se faire à trois et l'établissement des priorités de financement devrait être fait avec le gouvernement.

R. Lepp, EACL

- Il est en faveur de la collaboration des industries minière et nucléaire, car son entreprise a de l'expérience dans les systèmes télécommandés. Elle a mis au point des instruments qui permettent de localiser, à distance, les fuites dans les tuyaux et de les réparer. Ces tuyaux se trouvent au coeur des réacteurs nucléaires. Fermer une centrale pendant une journée coûte de 250 000 à 500 000 $. EACL compte aussi beaucoup de spécialistes de la transmission des données, qui pourraient être très utiles dans le domaine minier, par exemple transmission par FM de données multiples au moyen d'un seul câble.

J. McCubbin, Martin, McCubbin et Ass.

- Il croit à l'importance de procéder à l'automatisation des mines par étapes. À son avis, l'industrie minière pourrait tirer profit de l'établissement d'un protocole d'automatisation. Les entreprises de haute technologie pourraient se charger d'établir les liaisons entre les mines. Toutes les commandes et toute l'automatisation des mines devraient être interreliées et non pas fonctionner séparément.

P. Skillen, Instantel

- Il demande si on a évalué la possibilité d'appliquer le protocole MAP aux mines et si un exploitant serait prêt à jouer le rôle de chef de file dans ce domaine.

C. Mayer, OCM

- Il fait remarquer que les systèmes spécialisés et à intelligence artificielle deviennent à la fois pratiques et utilisables. Il faudrait qu'on songe à leur application dans l'industrie minière.

J.R. Roszell, Jarvis Clark

- Il est d'avis que les objectifs du colloque sont valables et que l'expérience devrait être répétée souvent pour maintenir l'élan. Il espère qu'il y aura une grande collaboration avec l'industrie, avec des objectifs bien précis.

E. Kossatz, Inco

- Plusieurs programmes de recherche et de développement sont exécutés séparément. Chaque exploitant veut quelque chose de différent. L'industrie devrait pouvoir former des groupes de collaboration, sans l'aide du gouvernement.

J. Udd, LRM

- L'USBM travaille activement à la mise au point d'équipement. À notre avis, le rôle du gouvernement devrait en être un de catalyseur pour la mise au point conjointe d'équipement par les fabricants et les exploitants miniers.

P. Pickerill, SPAR

- Il arrive souvent que les personnes qui auront à utiliser le produit ne soient pas présentes aux réunions, comme c'est le cas aujourd'hui.

W. Williamson, RSI

- Il faudrait réunir toutes les parties touchées par l'automatisation dans les mines. Elles doivent prendre un engagement à long terme. L'Association des manufacturiers canadiens est dominée par d'autres industries, mais elle ne compte aucun membre de l'industrie minière.

E. Cinits, CART

- Il parle des réunions de Paris et de Londres (mai 1985) et regrette que les Canadiens n'aient pas insisté davantage pour que le Centre international des innovations en exploitation minière, ou un organisme semblable, ait son bureau principal au Canada. Il pense qu'il sera très important d'entretenir des liens avec le centre américain. Il faudrait aussi tenir davantage de colloques comme celui d'aujourd'hui.

E. Dudgeon, CNR

- Il parle du rôle du CNR et signale que, à l'occasion, il y a interaction avec l'industrie minière. Le CNR prête ses installations spécialisées contre remboursement des coûts. Il joue un rôle complémentaire et établit des normes pour l'industrie.

J. Pathak, LRM

- Il fait ressortir l'importance de la mise au point de matériel comme moyen de réduire le déséquilibre commercial avec la Finlande et la Suède, des pays dont le marché intérieur est encore plus restreint que celui du Canada. Environ 85 à 90 % de leur production de matériel minier est exportée. Les Canadiens se montrent particulièrement innovateurs au plan des méthodes minières (méthodes d'exploitation VCR), mais ce n'est pas là quelque chose d'exportable. De même, il ne faut pas nécessairement mettre au point du matériel approprié à un système d'exploitation minière; l'inverse est aussi possible.

La plupart du temps, l'industrie minière s'exprime de façon trop générale, de sorte que les entreprises de haute technologie n'ont aucune base pour la conception de matériel. Les usagers devraient définir les caractéristiques de problèmes particuliers, établir les buts et paramètres de systèmes et transmettre ces données à une entreprise de haute technologie. Le travail de celle-ci en serait d'autant simplifié et lui permettrait d'arriver à un résultat beaucoup plus tôt. La plupart du temps, ces entreprises travaillent "au hasard".

D. Goldsack, UL

- La conclusion du MIT a été que le cycle de forage et de dynamitage en exploitation minière est maintenant chose du passé. Il propose, avec le soutien de l'HDRK, une machine d'exploitation continue. Il fait remarquer qu'on comprend encore mal les liaisons rocheuses et les paramètres régissant les possibilités de coupe. À moins de bien comprendre ces caractéristiques, il sera difficile de concevoir une machine d'exploitation continue pour la roche dure.

D. Ménard, CRSNG

- Elle présente les différents dossiers en vertu desquels le CRSNG accorde des fonds, indiquant qu'il y a actuellement environ 300 millions de dollars qui peuvent être accordés à la recherche. Elle donne des détails sur le CRSNG, son organisation, ses fonctions et la façon de demander des subventions.

M. Scoble, McGill

- Ce n'est pas toujours le matériel ou l'automatisation qui augmente la productivité. Il faudrait aussi étudier d'autres paramètres, tels que la gestion et les programmes d'encouragement. Il donne ensuite un résumé comparatif des industries minières du Royaume-Uni, de l'Afrique du Sud et du Canada, indiquant les tendances dans ces pays. À son avis, il y aurait dû y avoir au colloque des exploitants de petites mines, de roche tendre et de mines à ciel ouvert.

J. Wroe, Chef de cabinet du député NPD

- Le gouvernement de l'Ontario intervient davantage au niveau de l'industrie minière. Un Centre canadien de robotique ou d'automatisation minière s'insère bien dans les objectifs du gouvernement ontarien.

DISCUSSIONS

À la fin de la séance, J. Udd pose aux participants les questions suivantes:

1. **Quelle est votre réaction face à la proposition des États-Unis? (établir un centre international de recherche appliquée pour l'automatisation de l'exploitation minière et du percement de tunnels).**

Le consensus est sans contredit en faveur du soutien et de la collaboration, mais sans financement. M. Jowsey de l'HDRK, informe les délégués que M. Gantry, de la Colorado School of Mines, fait d'importantes représentations pour qu'un centre soit établi au Colorado. Il a fait une proposition officielle à la National Science Foundation de Washington (D.C.) et a obtenu l'appui de 6 ou 7 grandes sociétés minières, y compris quelques-unes du Canada. À son avis, environ 10 millions de dollars sont en jeu.

Certains membres craignent que le centre américain soit dominé par des entreprises ou des représentants de l'exploitation du charbon et que les problèmes de l'exploitation de la roche dure soient laissés de côté. On mentionne que les États-Unis ont pratiquement abandonné l'exploitation de la roche dure.

On s'attend à ce que, d'ici 10 ans, la robotique représente environ 10 % de l'automatisation dans les mines. J. Nantel propose qu'il y ait un comité canadien représentant les intérêts de l'industrie minière canadienne au centre. Tous les commentaires, toutes les propositions faites par les participants étaient semblables à celles de J. Udd dans son exposé de la position canadienne, présenté à la réunion organisée par la NSF au MIT, en novembre 1985.

2. **Quelles mesures voulons-nous prendre au Canada?**

On propose qu'il y ait une organisation au Canada permettant de réunir les exploitants miniers, les fabricants d'équipement minier, les universitaires, les experts-conseils et les représentants du gouvernement, pour étudier les besoins de l'industrie. Quelqu'un doit jouer le rôle de chef de file si l'on veut continuer de maintenir l'intérêt.

M. Scoble, de McGill, propose qu'on organise une réunion ou une conférence sur le même sujet, sous peu, pour continuer dans la lancée. On propose également que l'industrie prépare une liste "de souhaits" détaillée, qui serait distribuée aux parties intéressées.

3. **Par où commencer?**

On décide de former un comité spécial sur l'automatisation de l'exploitation minière composé des membres suivants: J. Nantel (Recherche Noranda, président), J.P. Roszell (Jarvis Clark), P. Pickerill (SPAR), E. Jackson (Int. Submarine), I. Barrie (ORC), E. Cinits (CART), J. McCubbin (Martin, McCubbin et Ass.), J. Kelly (Inco) et J. Pathak (CANMET/LRM). Les membres du comité devraient se réunir d'ici trois mois.

4. Quels sont nos besoins?

Aucune proposition n'a été faite concernant les besoins spécifiques de l'industrie, mais il est entendu que le comité spécial devra établir certaines exigences.

J. Udd résume les événements de la journée et met fin au colloque, remerciant J. Wilson et l'OCRMT d'avoir organisé la réunion et d'en avoir été l'hôte.

VIEWS AND OPINIONS OF MINE OPERATORS

HOW MINE OPERATORS VIEW AUTOMATION

M.C.E. Kossatz and J.G. Kelly, Inco Ltd.

Our company is committed to the introduction and enhanced use of new technology in our mines and plants to accomplish the dual objectives of:

a) Improving our safety experience.

b) Lowering our cost of production.

We tend to use the terms robotics and automation interchangeably. The terms artificial intelligence, process control, programmable logic control, remote sensing and mine monitoring are all lumped under computer control.

Examples of pure robotics in use in our mines are raiseborer rod handlers, certain parts of drilling machines, and bolting and screening machines. Further examples of automatic or remote controls include automated skip loading, weighing and hoisting, automated pumping systems, remote control trains, scooptrams, trucks, and automatic cage hoists. Further work is required for fully automated capabilities in both down the hole drilling and automated jumbo drilling.

Some examples of remote sensing include automated conveying systems, remote control ventilation systems, and remote control drainage systems. All of these systems require more robust and reliable sensing devices to cope with the hostile environments of high humidity, extremes of cold and heat, dust and other contaminants.

Future uses of electrically powered machines utilizing either battery AC or DC systems will continue to expand as the benefits become more obvious. Some of these benefits are: minimized fire hazard; less pollutants in the general atmosphere; reduced fuel handling costs; greater machine efficiency; and lower machine maintenance costs. Further development required for these systems includes low cost, on-line analysis and diagnostic functions to improve trouble shooting, lower overall costs and improve availability.

Future systems will of necessity embody some types of smart systems or artificial intelligence using both PLC and process control computers operated by high level software with an array of on-board sensors and data communication links. Examples of this type of application will include: autonomous vehicle movement underground; guided drilling; automatic scaling, bolting and screening; and automated guided tunnel-driving machines. The integration of some of these systems with a supervisory master computer will produce a totally automated, continuous-mining system.

The use of higher technologies will continue to expand in the mining business through all phases from exploration, mine planning, development and cost production. However, the rate of the expansion will be determined by the costs of acquisition of the technology.

Some of our experiences in technology acquisition, joint ventures or engineering contracts for high-tech equipment development in Canada indicate that the costs are very high and overhead charges are extremely expensive. Negotiations with Canadian companies in these areas have been difficult and frustrating to us due to a lack of entrepreneurial spirit and a perceived lack of willingness by these companies to share some of the risks associated with a new system development. Our experience indicates that these companies have a view that the mining industry in Canada represents a small market potential or a limited market for specific technologies. Their sights do not appear to be set very high. If a project is successful, there is good reason for worldwide export sales of Canadian expertise. In our experience, Canadian companies seem to be poor salespersons and have a limited imagination in the high-tech area compared to some of their American counterparts. Many high-tech companies who have derived most of their income from government contracts seem to have the highest engineering and overhead costs and are the least willing to take risks.

A second problem area in expanding new technology is attracting qualified people to the industry to help in the development of new systems and in the training and upgrading of the existing staff to keep the systems operating. The educational institutions hold the key to getting students interested in this field and producing graduates who can apply their skills and knowledge to the practical aspects of high-tech systems.

Another problem, from a mine operator's point of view, is to know what expertise is available and which companies have the skills required. One of the perceptions is to let a few larger mining companies develop the technology and if it has benefits the others can buy it. Participation cannot be limited to a few companies because it will keep the development costs too high. Our experience indicates that there is a need for technology transfer sessions similar to the ones sponsored by the USBM. This meeting may be the start of this sort of information sharing, where both developers and users of technology are brought together. We have fallen behind the United States in this area and need to catch up.

Both OCRMT and CANMET are to be commended for organizing the coordination of this initiative. We thank you for the opportunity to participate and welcome further initiatives very soon.

NORANDA'S VIEWS IN AREAS OF MINING

* Mechanization
* Automation
* Robotization

J.H. Nantel and G. Sauriol, Noranda Research Centre

INTRODUCTION

Noranda, through its Research Centre in Pointe-Claire, established a Mining Technology Division in 1982.

The activities of the Division since its formation have been in various fields such as:

- new mining methods
- development of in-situ mining technology for an oxide copper deposit
- development of novel ground control instrumentation
- ultrasonic mine survey probe development
- development of computerized mine layout ramp design systems
- investigation of novel mining equipment
- optimization of underground stope blast design
- study of potential applications of continuous mining activities in hardrock mines
- evaluation of microseismic monitoring technology for use in Noranda Group Mines
- potash mining research
- numerical modelling for mine design
- prefeasibility study of hydrogen fuel for underground equipment
- in-situ consolidation of backfill.

NORANDA'S VIEWS

From the research programs carried out so far by its Mining Technology Division, Noranda believes that, in the long term, further advancements in Mining Technology will be through mechanization, automation and robotization.

The success of a mining operation depends on the degree at which ground can be controlled. Even if, nowadays, there is still much research to be done in the field of ground control, our ability to excavate stable mine workings is fairly good.

Today, most of the ground failure related accidents happen while miners are working at ground control related tasks, i.e., scaling and bolting. Both of these operations are still performed manually. These ground support activities are required because miners must access mining areas. All of the heavy bolting patterns and screening would not be required to contain small pieces of loose rock if miners did not have to access these areas, or if access was limited to miners enclosed in rugged pieces of equipment.

This is to say our ability to engineer stable mines is good enough for rugged pieces of equipment, but it is far from being adequate for miners. So far, the safety of miners has been greatly dependent on their own ability to recognize ground conditions.

As mentioned in the MRL position paper, the evolution of technology must be gradual and proven step by step. Mechanization of scaling and bolting is slowly being introduced, automation of the drilling operation has started, and remote control operation of LHD's has progressed one step. There was some development and testing of automatic truck operation for underground mines in the early 1970's.

In the 1980's, the rapid development of microelectronics is offering new technologies to all industries, including mining.

In the second half of this decade, mining engineers will have to start working in close collaboration with their colleagues from other disciplines to invent new equipment and new mining methods. So far, we have been relying on equipment manufacturers to develop equipment and we have been designing our mines around these pieces of equipment.

To compete with the cheap labour rates and the higher grade mines of the Third World countries, the developed countries will have to engineer new, highly efficient mining methods. Automation and remote control are seen as the first steps to be introduced in the near future, which would improve both safety and efficiency. One operator could operate and supervise several pieces of equipment from one environmentally safe control room.

Today's priority for mine operators is to improve equipment availability. Machines are designed to operate within certain stress limits, but not all operators are aware of them. Often, operators have tendencies to go over these limits. Automation and remote control of these machines will require sensors to monitor the operation. At the same time, these sensors could be used to prevent a machine from operating above its designed capacity. This could bring the equipment availability to expectation and considerably reduce maintenance costs. High availability of equipment is imperative for remote control and automatic operation.

The ultimate goal of mining automation is to be able to operate everything, from drills to trucks, by remote control from the surface. To carry this out, sophisticated monitoring and control instrumentation will need to be developed, as well as the software to enable separate activities to be integrated into a more advanced mine planning and management framework.

One essential element is required to pull all this together. It is the emergence of low-cost, flexible, multifunction underground communication systems, capable of linking all aspects of the mine to the surface through voice, data and image transmission.

CONCLUSION

Canada is one of the most important countries in underground base metal mining. There is a good opportunity to develop secondary industries in high technology, and this is imperative for Canada's economic growth. Primary industry importance will decrease as richer ore bodies are found in other countries such as Brazil, Chile, China, and Zaire. High technology will soon reach these countries. If it does not come from Canada, it will come from countries such as Sweden, Finland, Japan, and France.

In 1986, Noranda will do mostly short-term research programs. It has potential sites available for field-scale testing of various technologies. Many other research programs could be initiated and the following are examples of research programs in which Noranda is interested:

- underground communications
- monitoring of equipment for breakdown prevention
- mine management assisted by computer
- mine electrification
- small-scale mining
- mobile and stationary equipment automation and remote control
- guiding device for drilling long, straight blast holes
- hydraulic transport systems
- new ways of breaking rock
- hydrogen-fuelled equipment
- backfill
- ergonomics
- diesel exhaust filters.

In the present depressed state of mining activity, it is increasingly important that the scarce funds within the industry, and those available through government agencies, be used efficiently on services that will ensure the survival of the Canadian mining industry.

THE NEEDS FOR MINING ROBOTICS - FALCONBRIDGE'S VIEW

Y.L. Su, J.L. Fuchs, and L.C. Gregg, Falconbridge Ltd.

In mining, the urgent needs at present are mechanization and automation. We can see the needs for the automatic train, skip, ITH drill, drill jumbo, and continuous miner, but have difficulty seeing the application of robotics.

The definition of a robot according to the Robot Institute of America is: "A reprogrammable, multi-functional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks". Any special purpose device, regardless of the complexity and/or intelligence, should be classified as automation, not robotics, according to this definition.

At Falconbridge, robotic technology is considered the lowest priority on our mining technology development list. Our approach toward the implementation of automation and computerization technology is:

- To keep abreast of the mechanization, automation/machine control and computerization technologies developed elsewhere, so that any opportunity for application will not be overlooked.

- To cooperate with other R&D organizations identifying areas for development and carrying out design-and-demonstration projects.

- To proceed with the step-wise implementation of mechanization, automation and computerization in our existing and future mining plants.

Therefore, we feel that a 'window, to the new development of the automation, computerization and robotization should be maintained so that we can promptly update our thinking. If the proposed centre at MIT can provide input in this area, liaison with the centre should be fostered. CANMET should act as a clearing house on this matter.

MEMORANDUM FROM HDRK MINING RESEARCH LIMITED

Position of HDRK Mining Research Ltd. on Mining Automation

M.E. Jowsey, Director of Research

HDRK Mining Research Ltd. has four equal shareholders: Falconbridge, Inco, Kidd Creek and Noranda, and the four member companies all have their own priorities relative to automation in mining. These priorities are generally developed to satisfy specific company needs and should be kept as their own individual responsibility.

HDRK MLR's mandate is to engage in major, innovative, long-range research and development. Mining automation will, in consequence, be looked at from a long-range point of view.

There are so many reasons why the mining industry should automate its equipment that it is hardly a debatable issue.

Automation in mining automatically includes the premise that it will be done in a safe and efficient manner.

Since HDRK is looking a long way down the road, it is hard to discount robotic applications. The short-term indications are that either robotics have not caught up with the industry, or the industry has not changed enough to accept robotics.

I would think that the industry would keep an open mind and would continually monitor potential robotic applications, but not actively pursue this specific technology at this time.

The biggest obstacle to overcome in making incremental or major changes is the lack of knowledge of the state of the art. The indecision or wasted efforts resulting from lack of knowledge of what is available is a cost the Canadian Mining Industry can ill afford.

The actions that Dr. Udd has proposed for CANMET are quite supportable, particularly if the emphasis is adjusted a little.

The exchange of information and data is fine as long as all the applicable information is there to exchange. A much greater emphasis needs to be placed on a method of gathering all the information possible, or not so possible as is sometimes the case.

Decisions relative to the direction of R&D 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.

There are indications that NSF is planning to establish University/Industry Cooperative Research Centres on remote mining. My reading is that the competition to become one of these Centres in the U.S. is intense. We would be well advised to let them settle this south of the border without indicating our preference, if indeed we have one.

MEMORANDUM FROM THE ONTARIO MINING ASSOCIATION

Bruce Campbell, Manager, Technical Services OMA

I was advised of your meeting in Sudbury on March 12 to discuss priorities in mining/mechanization/automation/robotization.

This is a subject of great interest; I noted your comment in your paper presented in Cambridge that "a determined move into robotics at this time would be viewed by industry as a radical shift", and did a little survey of our members to get their views.

Almost everyone agreed that more research should be done on robotics. Three-quarters believed robotics should be a fairly high-priority item. Nine companies said they would allow suitable robotics research to be done at their mines.

After discussion with several key people, I believe we should expect to move in stages, as implied by your sequence mechanization/automation/robotization, but we should have our eyes firmly set on the ultimate goal of robotized mining.

John, the nickel industry has in the past 10 years had a 71% reduction in accidents, and a 336% increase in compensation board assessments. If this trend continues for the next 10 years, the accident rate will be reduced almost to zero (actually 1.4 per 20,000 hours), while the assessment will increase to $11,400 per employee per year. This is an intolerable burden to be placed on top of the costs of preventing accidents in the first place.

I believe mining people are getting conditioned to accept the "radical shift" you mentioned, as a necessary means to survival. We need to accelerate this shift.

TELEX FROM THE POTASH CORPORATION OF SASKATCHEWAN, SASKATOON

Mr. W.E.G. Taylor, Research Mining Manager for PCS

Owing to reasons of fiscal restraint, the Potash Corporation of Saskatchewan will not be able to send a delegate to the above conference. However, by this letter we wish to express to you our opinions and suggestions for the conference.

1) It is our opinion that a national centre for mining machine automation and tunneling should be funded.

2) This center should be funded by industry, federal and provincial governments.

3) Regarding robotics, we feel that potash mining is not so dangerous as to require stand-alone robotic mining equipment. What we do require is mining equipment that can sense the quality and grade of ore and can pursue the winning of the ore with guidance from a human operator.

Therefore, it is our opinion that totally robotized equipment is not yet a requirement of our industry.

To explain with a brief specification:

a) A continuous mining machine of the future should be capable of sensing geophysical anomalies ahead of the machine, i.e., water, barren rock, collapse zones, ore grade, and discontinuities, and report by instrument reading to the operator any required action.

b) This future mining machine should be self-diagnostic and within economic reason self-maintaining. These capabilities should be translated into designs that record and monitor gearbox conditions, power requirements, oil debris and bearing clearances, and automatic controls that control machine advance, power input and 'on the go' bit replacement or sharpening. Self-maintaining designs should be self-lubricating, and able to clean and filter gearbox and hydraulic fluids, and adjust bearing clearances and caterpillar tread tensions.

These brief specification conditions should then report to a central 'maintenance planning' organization. As you can see from my specification, we are asking for a conservative step toward machine automation and reliability.

This is the message that I receive back from the various mining division managers.

As to the location of this automated mining and tunnelling centre, my maintenance and engineering people request that we try "Canada". As you may know, all major mining equipment in the potash field is manufactured in the U.S. and the variance between the two currencies is hurting our mining costs, plus the fact that all maintenance supplies and parts are of U.S. origin. This is a large proportion of our costs which, with support from Canada, could become an area of Canadian expertise (i.e., the Mandrell mining machine of Vancouver). This would also allow an infrastructure of engineering expertise to consolidate in our country.

VIEWS AND OPINIONS OF MANUFACTURERS AND CONSULTANTS

APPLICATION OF AUTOMATION TECHNOLOGY TO THE MINING INDUSTRY

Eric Jackson, International Submarine Engineering
and Peter Boorman, RMS Industrial Controls

INTRODUCTION

Many industries today, such as the pulp and paper industry, aluminum smelting, warehousing, wood harvesting, steel fabrication, and subsea oil production, have adopted automation techniques, often in special and fail-safe environments where safety is an important aspect. Mining on the other hand, both open pit and underground, has been more conservative in the adoption of this new technology, but could now take advantage of much of the technology developed for these other industries, with increased productivity and safety.

Mining automation can actually include four types of developments. These can be distinguished roughly as follows:

- Mechanization - the development of dumb machines to do manual work.
- Remote control - the process of providing the capability of controlling a machine while being physically removed from the worksite.
- Automation - this is the process of freeing operators from repetitive tasks. Automation has typically been low in operator interface, and is usually associated with turnkey systems.
- Robotics - this incorporates mechanization with the addition of sensing for decision making. It is also flexible automation.

In this paper, we use automation as a general term encompassing all of the above disciplines. We first describe the areas of technology that have allowed the present expansion in automation, and then describe how this technology can be applied to mining.

TECHNOLOGY

At this time, a wealth of technology is available, both pure and applied, that is applicable to automation in the mining industry. Advances in pure technology, which has driven the automation industries, have been mainly in the areas of fluid power and electronics. Application of these pure technologies in pioneering automation industries such as industrial robotics and remotely operated underwater vehicles has resulted in a knowledge base and a family of subsystems which are perhaps more important to the advancement of the automation industries as is the pure technology.

Fluid power has been instrumental in allowing the development of powerful machines with electronic control. Advanced components include high speed, electrohydraulic proportional valves which allow smooth, controlled motion of rugged equipment such as factory robots and small, powerful, efficient pumps with automatic control of pressure and flow. Hydraulic components are getting smaller and integration is being achieved in packaging. The same types of advancements are happening in pneumatics, but at a slightly slower rate. These together allow development of small, powerful, mobile, manipulative devices with electronic control capability.

The electronics industry has been the major driving force in automation in general over the past few years. Significant areas include integrated circuitry, power electronics, radios and communications equipment, electronic imaging equipment, and computers and interfaces. These have allowed the development of both automation and remote control of equipment.

Integrated circuitry initially enabled designers to make small, low-power packages to automate existing equipment and to transfer data to remote locations for analysis and control. Eventually, these designs became standardized or were replaced by more general-purpose equipment, such as digital computers. The microcomputer revolution has picked up from this beginning and allowed increasingly sophisticated machines to be designed.

Power electronics is allowing more efficient power distribution and motor control. This is important in mobile systems. Electric motors are more suitable than, and just as capable as, hydraulic controls in some applications.

The expansion of private radio communications band widths and the development of high-quality, low-cost radio equipment has allowed an unprecedented increase in remotely controlled systems, such as construction and logging equipment. Also, data transmission via satellite, and especially over standard telephone, is allowing automation and remote control of many more systems (e.g., pipelines).

Video cameras have been packaged for remote inspection of underwater locations, oil wells, and sewage systems. These devices are constantly getting smaller and of higher resolution. Real time computer analysis of video images is now becoming commonplace in factories. Work is being carried out to develop the same capability in mobile systems, where the a priori knowledge of the environment is much lower than that of the factory. This is allowing the automation of what were once considered highly skillful tasks.

Computers have been creeping into regular work tasks for some time now, bringing automation in many different types of work, from the manager's desk to the machines in the field, including devices ranging from automatic bank tellers to subway trains. Development of microcomputers and associated interfaces first allowed the replacement of special-purpose machine control hardware with general-purpose hardware. This allowed the adoption of common hardware packages for various applications and pushed the requirement for modularity of design, in both the hardware and the software to run it. As computers become more powerful, however, the same machines are being fitted with more sensors and more on-board intelligence and the machines are becoming "robotic". At the same time, more effort is being put into the capability for computers to interface with each other. For example, in General Motors' MAP program, computers from accounting to engineering to the factory floor are being interconnected, allowing the potential for an enormous degree of automation, which includes management optimization through linear programming.

APPLICATION OF TECHNOLOGY TO AUTOMATION

Although the pure technologies described above formed the raw materials for the initial development of automation industries, it is the presence of systems engineering capabilities and new subsystem components that is allowing the rapid proliferation of these technologies at the present time. Some of the engineering disciplines required in the automation industries are listed below. This is followed by a list of subsystem components.

Systems Engineering Disciplines

- automatic control and systems dynamics
- real-time software design
- operator interface design for remote control
- packaging
- power distribution
- propulsion
- navigation
- error-resistant communications
- device interfaces
- multidevice coordination, e.g., multisurvey vehicles, transit.

Subsystems

- small computer systems with real-time operating systems
- packaged hydraulic systems
- manipulators
- telemetry systems
- propulsion units
- instrumentation, e.g., navigation, obstacle detection.

AUTOMATION IN MINING

During the late 1970's, operator-machine interfacing was designed and supplied in the form of radio-control systems for the safe operation of scooptrams, locomotives, loaders, and skyline winch equipment. These incorporated digital on/off and proportional controls over narrow band FM UHF channels. Both productivity and safety were direct improvements in the operation of these vehicles. The same technology was applied to skyline carriage and winch controls and a project is currently underway for a radio-controlled mining winch operation in Ontario.

Applying more advanced sensing and automatic control capability to the above telemetry systems, remotely operated undersea vehicles with up to seven degrees of freedom manipulators with force feedback were developed for the offshore oil industry. Video feedback was supplied with these systems and they could be operated under real-time manual control or could be made to execute pre-described routines. This technology is now being applied to a land based vehicle developed at Carnegie Mellon University for clean-up of the Three Mile Island facility. Although not presently applied to the mining industry, a study is underway with a large mining company for the development of a robot to handle drill rods.

The subsystem technology described is now being applied to fully automatic vehicles and systems including unmanned under-ice survey vehicles and excavation and elevator systems. The electronics equipment takes the form of remote terminal units that control the motors, instruments, and polling systems autonomously. They monitor data for alarm conditions and report these back, along with regular status information, to the master station. The communications link is by radio, land line, or underwater acoustics. Thus a turnkey solution for the removal of ore and tailings in an open pit mine could be developed.

With the costs of machinery in mining, maintenance becomes an important consideration. Tool life could be extended by the incorporation of sensors and automatic controls in the machines. Furthermore, expert systems could be developed to support maintenance programs. An example of this is the program developed by CN for troubleshooting and maintaining locomotives. Also affiliated with maintenance is the problem of parts inventory monitoring and control. This can be automated, an example of which is the development of a fully automated warehousing system for Canadian Tire.

While full robotization in mining is probably still years away from being implemented, certain aspects and operations lend themselves very well to increased automation, e.g., drill handling, drilling, boring machines, and ore collection and processing. Productivity and safety would be direct benefits and machine tool life would also be greatly improved. Maintenance scheduling and parts inventory could be greatly automated. At this time, management information systems allow scheduling of work tasks based on up to date information from operations, accounting, and marketing sources. With a view to the mining operation of the future, knowledgeable decisions on automation strategies can be made today.

CONCLUSION

Increasing scales of automation and integration will be achieved as time goes on. The first steps consist of developing more automation at the physical level, while at the same time increasing the capabilities of management information systems. Thus productivity improvements can work upwards from individual machine control to multimachine tasking, to operations management, to profitability optimization dependent upon short period market situations and long period corporate strategies. Although we are in a formative stage, the time rate of change will be as dramatic as it has been in the so-called computer revolution. Thus, the opportunity for participation as Canadians is upon us and should be acted upon in a timely fashion. The formation of joint industry ventures and Government programs will be a good first step toward participation in this revolution.

NUCLEAR WASTE MANAGEMENT RESEARCH PROGRAMS

A Vehicle for Developing Mining Automation Systems and Equipment

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

Wardrop is pleased to have been invited to take part in this workshop on mining automation. It is clear to us that such initiatives are required to maintain Canada's position as world leaders in the mining industry.

It is equally obvious that Canada must develop new and innovative mining techniques if we are to remain competitive in world markets. However, our discussions with industry representatives indicate that they are primarily concerned with keeping their heads above water in these tough economic times, and as such, have limited extra funds available for researching alternative mining techniques and investing in new equipment.

The arguments for increased automation in mining are clear. Reducing labour costs could significantly reduce the cost of extracting ore from the ground and subsequent processing of that ore. Also, safety could be greatly improved by replacing people with automated equipment for dangerous tasks.

Unfortunately, the arguments against increased automation in mining are equally clear. The cost of developing, producing and implementing automated equipment and techniques will be very high, and much of the technology which will be discussed at this workshop today is a long way from realization. Mining operators also feel a strong obligation (moral and political) to keep people working. During tough economic times, even difficult and dangerous jobs are looked upon by workers in an attractive light.

I'm sure that so far, I haven't told the participants of this workshop anything you don't already know. Many of you today will be proposing possible applications for automation in mining. I would like to concentrate my comments on one possible route or path for development of automated mining equipment, specifically, nuclear waste management research programs. The current concept being assessed by the Canadian Government and the Canadian nuclear industry is the disposal of wastes deep in Canadian Shield plutonic granite. Similar concepts are being addressed in Sweden and the USA for disposal in crystalline rock, welded tuff, basalt and salt.

Through our involvement in this program, it has become evident to Wardrop that a great deal of effort will be required for development of equipment and extraction techniques to optimize the concept of disposal in hardrock. However, many of the activities that will be required in the disposal vault are similar to activities currently carried out in everyday mining operations, with the added restriction that they will be carried out remotely due to the high radiation fields. It seems reasonable that the Canadian Government and the mining industry could collaborate in the development of required techniques and equipment, with resulting technological spinoffs which could benefit the Canadian mining industry.

The disposal vault for nuclear wastes is envisioned as a highly regular room and pillar arrangement, located 1000 m below ground in plutonic hardrock. Extraction rates will be typical of very large mining operations. However, excavations will not have to follow irregularly shaped ore bodies. A large number of shafts will be required, ranging in size from 3 to 8 m in diameter. Shaft development systems will be required to introduce as little disturbance to the surrounding rock mass as possible.

Excavation techniques that minimize disturbance of the surrounding rock mass will also be required. As mentioned, excavations will be highly repetitive and regular, and therefore, definitely suitable for automated extraction techniques. Development of continuous hardrock mining equipment will be useful, if not necessary. A further requirement of the mining system is that it should keep the vault environment as clean as possible. Therefore, advancement in electric-powered equipment technology will be required. Remotely controlled equipment will be necessary for operation in radiation fields.

Related to excavation, automated systems for road and rock surface preparation will be required. Automated rock bolting equipment would find considerable use, along with techniques and equipment to locate and grout water-bearing fractures. Advances in other mining related techniques are also required. These include:

- fracture location and mapping techniques
- backfilling systems
- ventilation systems
- waste package emplacement and, related to this, automated equipment positioning systems.

A Canadian nuclear disposal facility is still a long way from fruition. However, construction and operation of such a facility will cost billions of dollars. A facility of this magnitude offers abundant opportunities for optimization and cost savings, and will require extensive research and development of equipment and techniques, beginning in the near future.

From the above discussion, it is apparent that many of the systems required for a nuclear waste disposal facility will be directly applicable to the Canadian Mining Industry, and their development will be of great value in helping this industry modernize and automate to maintain its world prominence.

We cannot speak for the Canadian Government, but it appears to us that the nuclear waste management program would be a suitable vehicle for advancing the state of automation in mining. We encourage the Canadian Mining Industry to explore ways to cooperate in this endeavor, and Wardrop looks forward to contributing our expertise to maximize the mutual benefits that may be achieved by both groups.

POSITION PAPER ON ADVANCED MINING TECHNOLOGY

Spar Aerospace Ltd.,

Remote Manipulator Systems Division

INTRODUCTION

Spar Aerospace Ltd., Remote Manipulator Systems Division, decided to introduce its technology to the mining industry, as a natural extension of its successes in bringing remote control, robotic and automation technology to inherently hostile environments, such as space and nuclear.

Having been actively involved with the mining community in Canada since the beginning of 1985, and with the international mining community since November 1985, Spar has embraced productivity, as well as and ahead of safety, as a driving force for innovation and automation in the mining industry.

Spar has made a firm corporate commitment to the mining industry and will actively participate in industry initiatives to introduce advanced technology.

SPAR TECHNOLOGY

Under the general heading of advanced manipulation and control, Spar brings proven skills and performance to the mining industry in the following areas:

- robotics
- remote manipulation and control
- automation
- hierarchical control of multiple systems including resolved rate machine control in six axes
- mechanisms/handling and positioning aids for confined geometries
- machine vision
- force-moment sensing
- sensing/monitoring systems
- mechanical/electrical/hydraulics engineering.

Spar has a strong base in applied R&D, and has the capability to take its innovations to prototype testing and eventual full production. It is prepared to address a broad range of product possibilities from packaged monitoring or control systems to automated or continuous mining systems in hardrock, soft-rock, or uranium mining.

SPAR ACTIVITIES IN MINING

Spar's first major project in mining has been the development, from concept to prototype production and testing, of a remotely controlled and semi-automatic roof bolting and screening machine. It is unique in combining the bolting operation with optional screening, and provides a major step forward in both productivity and safety.

Other activities fall into three categories:

a) Scientific research into advanced technologies which at some future date could introduce step changes in productivity.

b) Heavily funded market research aimed at identifying appropriate directions for product development funding.

c) Market development activity, both in Canada and the U.S., to exploit Spar's technology in new hardrock mining applications, and in coal mining/softrock mining.

SPAR POSITION

The U.S. mining industry has created a Centre for Innovative Mining Systems at MIT, and has solicited Canadian support. Spar has formed the impression that this centre will address coal mining concerns almost exclusively and will contribute little technology that will be of benefit to most of the Canadian mining community. Spar's interest includes coal mining and it will continue as a private company to interface with this U.S. Centre. However, it believes that Canadian interests would be better served by the formation of a parallel centre in Canada to focus on issues of concern to the Canadian mining industry. Spar would expect to be actively involved in the affairs of such a Canadian centre.

For Spar, and probably for other companies in the business of advanced technology, the mining industry is new, different, and largely uncharted territory.

Spar is committed to continue its growth in the mining industry but, in spite of heavy expenditures on market research, has not been able to identify a real consensus within the established mining community as to the types of products or mine operations on which it should focus its development efforts.

The company, and the advanced technology sector it represents, is far from being risk averse. It senses a worthwhile business opportunity, but for the most part is still flying blind. It desperately needs direction from the mining industry. Its confidence in committing its resources and its reputation would be dramatically improved by a solid commitment to innovation from those established mining and mining equipment companies which can best assess the risks and benefits associated with changes (either incremental or major) in mining technology and methods.

Advanced technology companies are, for the most part, small in size, i.e., smaller by orders of magnitude than the mining companies they seek to serve.

To gain the most from these limited resources, Canada's mining community must be prepared to work intimately with the advanced technology sector, and to participate to the maximum extent possible in the process of innovation.

Spar recommends a cooperative approach to innovation involving four identifiable groups within the industry:

- The mining companies, to identify the specific products or processes where innovation is most desperately needed, and as the ultimate beneficiaries of the innovation, to take the primary role in sponsoring development efforts.

- Established mining equipment companies, to support the development effort, to contribute design and manufacturing expertise related to the mining environment, and to adapt product lines to accommodate innovation.

- The advanced technology companies, to develop new approaches to the solution of mining problems and to participate with mining companies and mining equipment companies in implementing new techniques and in integrating advanced technological features into mining equipment and processes.

- Government, to act as a clearing house for information, as a facilitator/catalyst for cooperative development efforts, and as a supplementary source of funding for these development efforts.

Spar does not wish to operate autonomously in the mining industry. It seeks to cooperate with mining companies and mining equipment companies to identify the need for and to develop, produce, market and service remote and automated mining systems, in a manner that will provide maximum leverage of the proven skills of each of the cooperating parties.

A LOOK AT REMOTE SYSTEMS TECHNOLOGY AT THE CHALK RIVER NUCLEAR LABORATORIES

R.M. Lepp, Atomic Energy of Canada Ltd.

INTRODUCTION

Interest in remote systems technology is growing rapidly as manufacturing and mining industries in North America strive for greater productivity to compete internationally. The Canadian nuclear industry, which also has to compete internationally, has been developing remote systems for many years to carry out the inspection, maintenance and replacement of equipment in high radiation environments.

The remote systems developed in recent years at the Chalk River Nuclear Laboratories (CRNL) operate under computer control and use closed circuit television for vision feedback. During an inspection or a repair, the operators of these systems are protected from high radiation by shielding and by distance.

In the future, the nuclear industry will need increasingly sophisticated remote robotic devices for handling highly radioactive wastes, for decommissioning obsolete nuclear power stations and for the maintenance of operating nuclear installations. Initial contacts indicate that similar remotely operated systems will become increasingly necessary in the hardrock mining industry, to increase productivity and to remove workers from the more hazardous areas of a mine.

OUR CAPABILITIES

The remote equipment needed to meet the needs of the nuclear industry is highly specialized and complex, and in the past was not available commercially. Consequently, the industry has developed in-house capabilities over the years, to design, develop and produce these remote systems. An important centre of this activity is the Remote Systems Technology Group, within the Mechanical Equipment Development Branch at Chalk River. This group comprises engineers, technologists and designers, who work as a team to take a remote system project from the conceptual stage right through to a fully tested system, ready for use at the nuclear installation with the need.

Most of the development work is carried out in an R&D laboratory environment at CRNL, where the various disciplines required are close at hand. This includes:

- mechanical and electrical design
- control systems expertise
- metallurgy
- stress analysis
- reliability and maintainability capabilities
- project management.

In addition to these more traditional engineering capabilities, we are carrying out R&D in the important areas of data highway technology, electronics for demanding environments, advanced nondestructive testing methods, multivariable control and the application of expert computer systems.

The data highway technology developed at CRNL should be of particular interest to the mining industry. This technology, which is based on cable television, is extremely reliable and flexible. Its major attribute is that many different information signals can be simultaneously sent over a single cable using frequency modulation techniques. Consequently, the same cable can be used for such diverse things as voice communications, control of remote equipment and various monitoring functions.

EXAMPLES OF SUCCESS

When unexpected system failures occur in a high radiation area of a nuclear installation, Chalk River is frequently asked to respond. Because of the cost of lost electricity production, schedule becomes an important factor as we develop specialized remote systems and supervise their use at the site. Two examples of such situations are given in this section.

Large pipe leaks developed in one of the main heavy water systems in the Douglas Point Reactor. It became necessary to design, fabricate and fully test a remote system to inspect and repair these damaged pipes in a high radiation area. The team, based at CRNL, successfully completed their assignment in 8 months and the reactor returned to service. Field repairs were carried out from a remote control room using closed circuit television.

A second major remote system developed at CRNL, was for the inspection, cleaning and gauging of pipe flange surfaces at the face of the reactor. This was part of the pressure tube replacement program for the Pickering reactors. Again the need was in a high radiation environment, where humans cannot work for extended periods of time. The requirements were for a highly reliable and fail-safe remote system that would not lock on to the reactor in the event of a mechanical or electrical failure. The final system built and tested at CRNL uses microprocessor control with CCTV for vision feedback.

FUTURE NEEDS

In the nuclear industry, we see a growing long-term need for more remote systems, as the number of nuclear installations increases, as installations get older, and as we try to extend the operating life of plants. Large-scale systems will be required for:

- equipment inspection, maintenance and replacement in existing power stations
- decommissioning reactors that have been shut down
- handling, storing and retrieving radioactive wastes.

In today's environment, there are commercially available delivery and control systems that can often be used as building blocks for the final system. However, there is a need for expertise, as it exists at CRNL, to integrate the various building blocks and develop the special 'end effectors' required.

This is a need that will grow in the longer term as remote systems are used for increasingly complex tasks. One way of maintaining this capability at CRNL is to make this talent available to the Canadian hardrock mining industry. In this way, we can ensure a long-term benefit to both the nuclear and mining industries.

TECHNICAL DIRECTION FOR MINING AUTOMATION

Martin, McCubbin & Associates

INTRODUCTION

> "It must be considered that there is nothing more difficult to carry out, nor more doubtful of success, nor dangerous to handle than to initiate a new order of things."
>
> Machiavelli

The forthcoming revolution of automation in mines will undoubtedly need guidance from all sectors represented at this workshop. Martin, McCubbin and Associates have been involved as systems engineers for real-time control in a wide variety of industrial automation projects. We view the automation of mining as an area offering great potential, but having considerable challenge in terms of design and development of innovative solutions.

Not surprisingly, underground mining offers one of the better examples of an industry that would greatly benefit from the application of modern methods of automation that would remove the miner from the hazards of the workplace while allowing for increased productivity. Trends indicate that future North American underground mines will be deeper and will have a lower grade of ore. These deep mines will be more hazardous to work in and more costly to operate. Technology that would remove workers from the dangers of the underground environment while improving productivity would be welcomed by mining companies.

The speed at which mines automate their mining processes will be driven by the relative cost of operating a mine safely using old methods versus that of using newer technology. Current technology can offer some individual components of automated systems, but such systems are by no means complete or integrated. Development of integrated mining systems is possible and highly desirable, but these systems are still in the future.

SCOPE

> "Man is limited not so much by his tools as by his vision. Historians tell us that the notion of the earth being round had been discussed for five hundred years before Columbus' time. What Columbus did was translate an abstract concept into its practical implications."
>
> R. Pascale/A. Athos, Economics of Innovation

The scope and number of problems that must be considered before a truly automated system of mining is in place are vast. The day that underground mines will be completely automated with no personnel required underground is still in the future. However, the need for constantly improving technology in mines is a fact. One of the major areas that may well prove to be a driving force behind technical innovations is increased use of computers to carry out mine planning and operation on a daily basis.

There will be many areas of the mining process that will require development of software to control, monitor and report on processes in the mine. Each process that is to be automated in the mining operation, from rock breaking to removal of the ore to surface, will require its own particular control algorithms in the computer program used for control.

- management planning
- operational planning
- mining
  - drilling
  - blasting
  - continuous mining
  - material handling/transportation/hoisting
  - backfilling

- mine monitoring
  - maintenance
  - rock mechanics
  - mine environment
  - occupational health and safety
- underground communication systems
  - environmental monitoring.

TECHNOLOGY ASSESSMENT AND DIRECTION

> "If you talk to enough people about technology assessment, the concept begins to sound as marvelous as motherhood. Except in this case, nobody knows how to get pregnant."
> N. Laserson, Innovations, no. 27 (Jan. 1972)

In our experience with the mining industry, Martin, McCubbin and Associates have witnessed a lack of cohesiveness in the mining community with regard to the approach to automation. The large distances, intercompany rivalry, differing mining methods, and the lack of a large, distinct market for suppliers have all hampered the introduction of new technology to mining. The following ideas were put forth as an attempt to solve some of the problems mentioned and unify the Canadian mining industry in its development of mining automation:

- formation of mine automation interest groups
- protocol system for mine automation communications
- remotely accessible, monitoring/control instrumentation
- communications systems
- integration of all levels of software use.

Automation Interest Groups

It is only through discussion involving members of each sector that the needs and capabilities of each group can be achieved. To avoid the problem of 'reinventing the wheel', avenues of communications such as this workshop should be encouraged. 'In-house' development of software by mining companies has created many excellent software packages, unfortunately these packages tend to remain proprietary and other mines must develop similar systems alone. Small mines do not have the capability to support a 'computer department' and thus cannot remain technically up to date. In many cases, companies can recover some of the development costs of the software and share in improvements to the software made by other mines.

Automation Protocol

The efficiency and usefulness of any form of advanced system automation system is dependent on the software and control algorithms that are resident in that system. One of the problems inherent in any automation system is the degree and ease with which the software of a system can interface with the operator, outside environment, and system hardware. The communication system in a mine must be compatible with each component of the automation system.

Nothing can stop the introduction of automation in mining more effectively than a lack of standards from which to work. A major problem that has hampered automation of factories is the incompatibility of equipment from computer and control manufacturers. Proprietary communication protocols commit a customer to a particular product line - assuring repeat business for the vendor and a major problem for the customer.

The usual result of mixed systems is an increase in costs for an automation project of 30 to 50% to pay for technology to interface incompatible systems.

The mining industry is fortunate in that it lags slightly behind other industries in the development of automation. Thus, we can learn from other industries' mistakes. Two industrial protocols that are currently gaining popular support are MAP (Manufacturing Automation Protocol) and TOP (Technical and Office Protocol). The MAP system, designed for the factory floor, and the TOP system, intended for the engineering and office environment, are protocol standards that have been created by end users stating their requirements, not suppliers. MAP and TOP are both examples of formulated systems for discussing and defining specification requirements, implementation of communication, performance and testing, and future developments.

As a participating member of the MAP interest group in Canada, Martin, McCubbin and Associates recommends the development of a communications protocol standard using the guidelines of MAP and TOP standards, but with the special needs and interests of the mining industry in mind. A study of such a standard should review both the hardware and software layers of the protocol itself. Such a study would probably result from modifications of the MAP standard.

Sensors and Instrumentation

There exists a need for improvements in instrumentation used for automated mining equipment. Much of the instrumentation used is borrowed from other industrial applications. There is a great need for instruments that will provide information on all aspects of the mining process. For example, low cost, coarse accuracy instrumentation and sensors that are easily replaceable are needed for the following areas:

- ventilation
  - air velocities
  - toxic gas sensors
  - dust sensors

- rock mechanics
  - rock fracture (microseismic rockburst)
  - strain gauges and extensometers

- production
  - equipment monitoring
  - geological sampling.

Many aspects of mining are not encountered by other industries. It is often in these applications that instrumentation does not exist or is prohibitively expensive.

Communications Systems

The underground communications system at a mine will provide the backbone for any automation system. The communications system will have to operate in conditions that will be considerably more harsh than factory environments. The nature of mining dictates that the communications system for automation data will have to accommodate frequent moves and reconnections.

The underground communications system could form the bottleneck for the automation project. Without a good high-performance communications highway for automation signals to be passed on to other computers, an automated mining system will become slow and difficult to operate.

Integration of Software

Each individual automated process will produce data useful to a wide variety of technical and management personnel.

The goal of integrated system software is to provide user specific data to all levels of mine management. This goal is possible with today's technology.

The integration of the levels of software is a commendable goal for which to aim. The ease at which all levels of staff can use information obtained by the automation system will greatly aid in the planning and operation of a mine. Automation systems are capable of generating overwhelming amounts of data on their operation. If data generated by one level of the system cannot be analyzed by another, it becomes wasted information.

CONCLUSION

Automation of a mine will bring a widespread use and dependence on the computer. It may be an understatement to say that not all mining personnel would be comfortable using a computer. Old ways die hard, but a committed effort toward automation will allow the mining industry to reap the benefits recognized by other industries. These other industries have paved the way in some instances and paid a much higher price for technology development. Mining should use this existing technology as a stepping stone to solving the difficulties that are unique to mining.

VIEWS ON MINING AUTOMATION

Karl L. Mayer Ontario Centre for Microelectronics

It is generally recognized that further instrumentation, mechanization and automation will be required to keep the Canadian Mining Industry competitive. To achieve such progressive automation in the time frame required, a considerable investment in equipment R&D will be needed.

Experience in other industries has often shown that it is not efficient to develop complex production equipment just for internal use. Expenditures may not be recoverable through increased production efficiency alone and the development effort to fully optimize equipment is much more effective if a multitude of users provide feedback to the designers.

Although there is extremely valuable experience and knowledge of world class caliber present in the Canadian mining industry, and machinery innovations are being implemented, a strong Canadian mining equipment industry has not developed.

The extensive use of computer and communication technology to mining equipment and total mining systems is unavoidable and will elevate equipment and operations to a new plateau of capability. This evolution to highly automated systems presents an opportunity window for the Canadian industry to establish itself as a world supplier of a new generation of mining equipment, thereby utilizing the experience and knowledge base present in this primary industry. A Canadian mining equipment and support industry could have the advantage of a national market and the opportunity to develop equipment in closer cooperation with mining experts.

A new generation of mining equipment and total mining systems will be based on an intimate combination of mechanical equipment with computers and software. Coincidentally, software technology is also in an evolutionary phase where so-called 'expert systems' are becoming practical. The underlying idea is to capture rules-of-thumb or experience-based conclusions in software and approximate, in a limited area, the reasoning of humans. With the methods being explored, it becomes easier to develop systems whose basic function is not realistically expressible in mathematical terms or algorithms.

In the development of flexible machinery, which is exposed to a wide range of operating conditions, the application of expert system methods could be appropriate. If it is possible to attain optimized operation over a wide range of conditions, by capturing the experience of experts and operators in software, highly efficient automated operations could result. The feature of expert systems to provide insight into their 'reasoning process' by displaying or printing out the rules and data used to arrive at conclusions, allows close interaction with a human expert during development and operation.

In these areas of advanced software, Canada has also significant expertise based in universities and in industry. However, the task remains to create a viable structure combining these knowledge bases with proper financing and international marketing capability, to create an industry that will provide new jobs and exports while employment in conventional mining and foreign income from Canadian mining products continue to diminish.

VIEWPOINT ON MINING AUTOMATION

Robert B. Werden, P.Eng.

Blackbox Controls Ltd.

REFERENCE

Blackbox Controls Ltd. has been manufacturing and supplying digital UHF radio remote control systems to the mining industry since 1977. These systems were instrumental in the development of VCR techniques at Inco Ltd. in Sudbury.

Today, Blackbox Controls has over 150 systems working in Canadian mines, representing almost half of our production. Our mining customers include Inco Ltd., Noranda, Kidd Creek Mines, Mattabi Mines, LAC Minerals, Pamour Mines, Falconbridge Mines, Brunswick Mines, IMC, Sherritt Gordon Mines and Hudson Bay M&S. Mining machinery manufacturers using Blackbox Controls include Wagner, JCI, Eimco, CMS Inc., Marmon Transmotive & Hunslet Engines Ltd.

MINING AUTOMATION OVERVIEW

Mining, like most other industries, has to live with the economic facts of life: produce at low cost or you won't survive.

Automation can be a major factor in attaining lower production costs, however, automation by itself, without due consideration to an integrated systems approach to work and process flow, can often lead to negative results.

A highly automated large-scale mining operation would likely contain some or all of the following:

- a data collection and control system
- a mine-wide voice and data communication system with fixed point access and wireless capabilities
- remote wireless control of mobile machines, the operator in line of sight
- remote TV closed loop machine manipulators with operators at surface or central control station
- mobile machine automatic location and status systems
- microprocessor control of fixed and mobile equipment.

Some, or all of these features should be integrated into one overall distributed, intelligent system.

Data Collection and Control Systems

There are many small- and large-scale data collection and control systems on the market today which are proven in surface control environments. Many of these could be adapted to mining automation and control.

Mine-Wide Voice and Data Communication System

Communication in a mining environment is considerably different than communication on the surface where VHF, UHF and other radio signals work quite well. In the mine situation, none of these work as well as they do on the surface, particularly with regard to range.

Some suitable methods of communication in mines are as follows:

a) Inductive coupling over existing power lines, piping and other conductors:

This can work well for voice communication and low Baud rates (data transmission rates, i.e., bites/sec), not requiring real-time controls. Since little additional cabling is required, the installation cost is kept low.

This method is not suitable for video or other high Baud rates, nor is it a highly reliable data transmission medium.

b) Coax leaky cable transmission into VHF/UHF range:

This is used for voice communication and is capable of handling high Baud rates including video. Cost of cable and transmission equipment are high. Installation of cable is also a major undertaking. Both the coax leaky cable and the inductive coupling suffer from lack of distant communication away from the cable, being limited to a few, or at most, tens of feet.

c) Hardwired main trunk systems:

Nearly all data collection and control systems used today operate over hardwire systems (sometimes with radio links) or, more recently, with fibre optics. These hardwire links offer high data rate, good reliability and performance. We recommend a combination: the main data collection and control system (by a hardwire trunk), local area tap-off points for voice in secondary drifts using inductive coupling, and for area coverage and mobile equipment, UHF radio. We feel the use of specialized sub-systems, integrated into a total communication system, may offer the best combination of performance and cost.

Remote Wireless Control of Mobile Machines, with Operator in Line-of-Sight Mode

This method usually requires only one way or open loop communication, i.e., operator to machine, since operator gets visual and audio feedback directly. Blackbox Controls has over 100 such systems in operation in various mines. These radio links will transmit over 100 metres, in relative line-of-sight. However, due to restraints other than signal propagation, their use is often limited to 100 feet or less. The use of remote radio control can lead naturally to the use of a remote operator with video feedback, beyond line of sight control. The interface necessary to do this between the electronics, the communication system and an electrohydraulic or electromechanical interface on the machine, has already been done.

Remote TV Closed Loop Machine Manipulators with Operators at Surface or Central Control Stations

A manipulator (as distinct from control panel) consists of machine-like controls, often with tactile feedback on joystick controls or, in some cases, head-controlled monitors which allow the TV camera on the machine to follow the head movements of the operator at the manipulator station.

This mode requires two-way communication: the control of the machine with required commands and video and perhaps audio feedback to the operator to close the control loop.

In our opinion, the manipulator method is superior and tends to be operator friendly.

MOBILE MACHINE AUTOMATIC LOCATION AND STATUS SYSTEMS

To keep track of work flow and machine vital life signs, it is necessary to know the machine's location and status. An automatic system can help to organize this aspect of overall mine control. One method is to have locator devices fixed through the mine communication system at key locations and fit each vehicle with a pickup and transmitting device. When the vehicle passes a locator, its signal is picked up and transmitted from the mobile machine to the data control centre. Each locator is coded, indicating its location in the mine. This system would periodically poll the data machines for such data as full load, empty or other emergency service data. Infrared devices are often used for locators.

Microprocessor Control of Fixed and Mobile Equipment

Outboard microprocessors can be used to advantage for fast real-time control of subtask, as well as data compression to reduce communication link traffic. For example, in a scooptram, the operator might give a single command to load. The microprocessor could initiate a sequence of events, including lowering the boom, rolling the bucket forward smoothly to a proper digging position and moving the machine forward into ore in one smooth continuous action. A microprocessor would then initiate a process to roll the bucket up, raise the boom and reverse, to a preset position where the operator again would take over. The operator would then initiate a new task by turning the machine 180° and going down the tunnel. This could also manoeuver the machine into a wireless guidance system where it would travel to the ore pass, dump and return to the workplace unmanned.

METHOD AND DEGREE OF AUTOMATION

There are two major paths to machine automation:

1) Installation of artificial intelligence on the machine.

2) Link the machine via a communication path to a central intelligence, which may include a person 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 the 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 person/machine interface.

Whenever the job is multitasked and more general in nature, with a certain amount of random variations, the human controlled or aided approach is required. This may utilize 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 person hours, previously wasted in getting ready to go underground and to and from the workplace, can be put toward productive work, particularly when the remote location is at the surface.

DANGERS OF AUTOMATION

Automation in its ultimate form will probably be a robot machine, which in response to a complex task request, will carry out all the procedures and subtasks necessary to meet the request.

Although there are now abundant examples of industrial robots for fixed, well-defined tasks, there are few proven mobile robots for general tasks.

In those instances where the machines are almost completely robotic, one can expect fairly massive R&D expenses and person time to have been spent. Ocean exploration is one example where many years of trial and error and millions of dollars have been expended on hardware and software.

Robots may not be the first step one would want to take when one is considering mining operations.

Another hazard in automation is in regard to the overall reliability and efficiency of an integrated system. One needs the integrated system approach to reach higher operational efficiency. However, we do not want to be exposed to partial or total operation shut-down because of failures in the system.

AVOIDING THE DANGERS AND FORGING AHEAD WITH MINING AUTOMATION

In our view, a realistic scenario for continued upgrading of mining automation should consider the following:

- An overall mine automation strategy to suit the particular mine based on size, life expectancy, and other specific conditions.

- A realistic assessment of the degree of automation that will be cost effective based on the resulting savings expected or other benefits such as personnel safety.
- An integrated system design with distributed intelligence, allowing phased-in features and expansion.

CONCLUSION

We firmly believe that further mining automation is in the best interest of the mining industry for improving the economics of operation. We, in Canada, should not let ourselves fall behind, either in automation of mining or in the production of hardware and software to support such automation.

VIEWS AND OPINIONS OF UNIVERSITIES AND GOVERNMENTS

THE CENTRE FOR ADVANCED RESOURCE TECHNOLOGIES

Edward Cinits, M.Sc., CART

HISTORY

In the summer of 1982, the Federal Government introduced the National Training Act with its new approach to more direct federal intervention in the setting of training program priorities across Canada. Later, in the fall of 1982, the College of New Caledonia made application to the Honourable Lloyd Axworthy, the Minister of Employment and Immigration at that time, for a grant from the new federal Skills Growth Fund "to establish an advanced technology training centre oriented towards the needs of the forest-related and mining resource industries".

The application received strong support from the British Columbia Ministry of Education and from the Canada Employment and Immigration Commission (CEIC), which resulted in a grant of $2,781,000, of which over $2,500,000 came from the Federal Government's Skills Growth Fund; the remainder came from the Provincial Government. These funds provided facilities and equipment for training in Computer-assisted drafting (design)/Computer-assisted manufacturing (CAD/CAM) and numerical control systems.

After extensive discussion, it was decided that the most effective model for the structure and operations of the proposed new advanced technology institute was an independent Centre, with a separate, predominantly industrial Board, free from the control and regulatory requirements of a Provincial Ministry of Education.

By December 1983, a society was incorporated in the name of the North Western Foundation for Advanced Industrial Technology (NWFAIT) - as a non-profit foundation. The society in turn incorporated a subsidiary called North Western Technology Ltd. as the operating arm of the Society. The Centre for Advanced Resource Technologies is an operating division of North Western Technology Ltd.

MISSION STATEMENT

> The broad mission of the Centre for Advanced Resource Technologies is to assist in the improvement of productivity in the Canadian Forestry, Mining and related industries through an effective process of technology transfer and to stimulate the development of software and manufacture of equipment for resource industries in Canada.

To accomplish the CART mission, a number of strategies will be employed, including:

- Evaluation of the most advanced technologies available and their adaptation to the resource industries.

- Demonstration of new technologies with emphasis on their potential application in Canada's resource industries.

- Research of Canadian resources and manufacturing processes in order to increase the value added to the product.

- Education and training to upgrade both technical personnel and management.

- Applications engineering liaison between equipment manufacturers and industry users.

- Technological services and expert consultation on the selection and application of new technologies.

The National Research Council (NRC) has viewed CART as complementing its own efforts in assisting Canadian industry. NRC has signed a contract with CART whereby an NRC Industrial Technology Advisory Service is located on CART's premises. BC Research is very interested in using CART's CAD/CAM installations for industrial engineering applications, and other equipment for remote sensing applications. To that end, the establishment of a microwave telecommunications link between CART and BC Research has been agreed upon. BC Research and NRC have agreed to locate additional liaison offices at the Centre.

THE FUTURE

The Centre for Advanced Resource Technologies (CART) currently has approximately $2.2 million invested in CAD/CAM hardware and software, plus an additional $1.2 million of software donated by one of the leaders in the CAD/CAM industry. CART now requests $9,186,000 spread over 5 years in order to complete the advanced technologies facilities and to provide support for the Centre's operation.

The capital-operating request is to be covered under the Canada-British Columbia Economic and Regional Development Agreement (ERDA). This is a Department of Regional Industrial Expansion (DRIE) umbrella agreement which provided a means to achieve greater cooperation and coordination between the two governments in realizing the economic and regional development potential of the province.

The $9,186,000 requested is to be used to complete a National Centre of Excellence in the Forestry and Mining Resources. In order to fully meet the commitment of its mission, CART intends to establish a Centre having national stature for the understanding of CAD/CAM, Automation, Laser, Fibre-Optics, Process Control and Instrumentation and the application of these technologies to the forestry and mining industries.

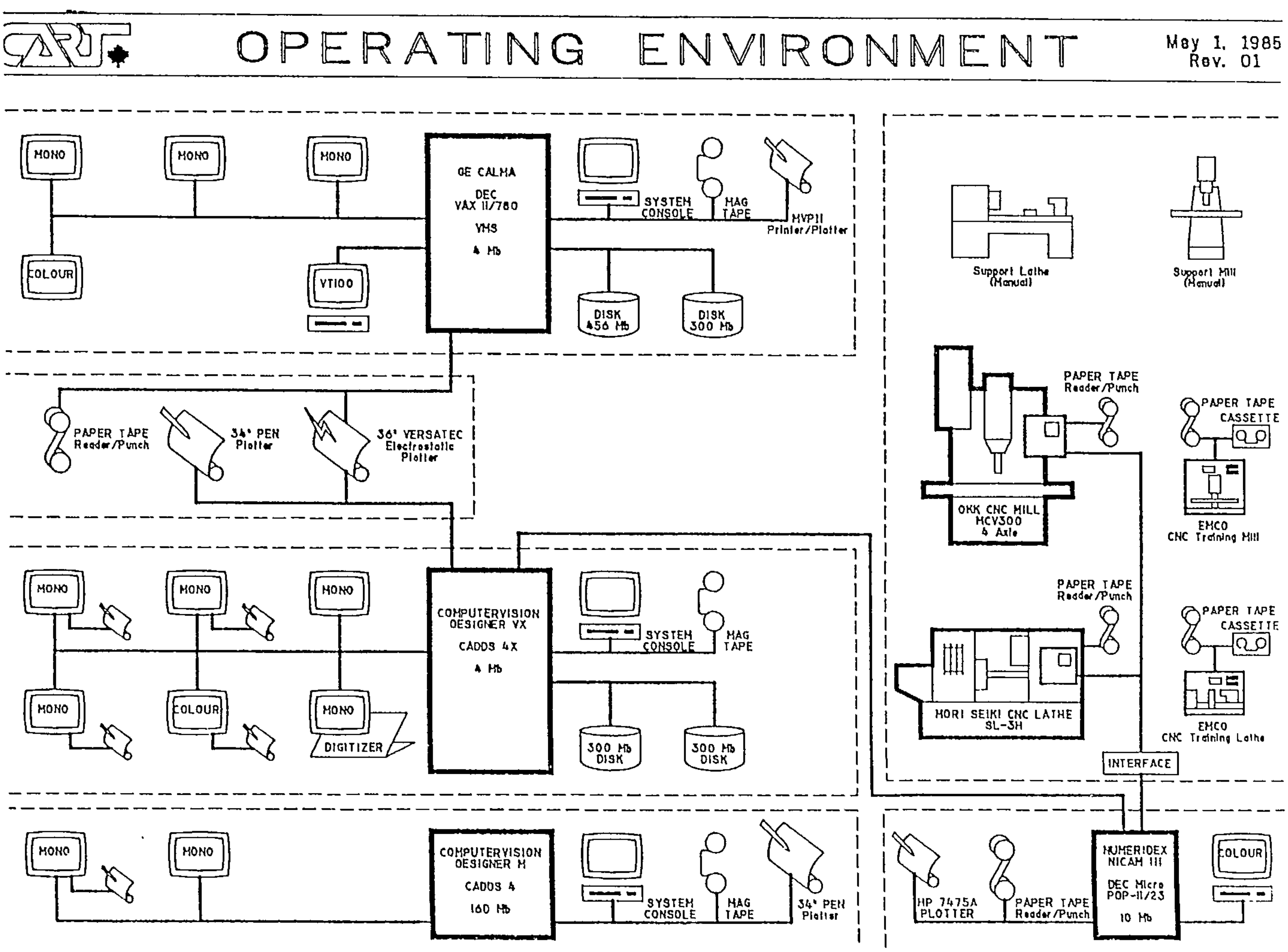
CAPITAL FINANCIAL REQUIREMENTS

The following table shows the expected expenditures on equipment and installation for the various technologies that will be pursued at CART.

	Year 1	Year 2 ($ 000's)	Year 3
CAD/CAM Hardware	490	290	50
Process Control	400	400	315
Lasers/Fibre-Optics	450	550	400
Robotics/Automation	1,100	1,280	200
Numerical Control	530	570	150
Instrumentation	120	270	-
	3,090	3,360	1,115
Total 7,565			

PROPOSAL

The Centre for Advanced Resource Technologies is prepared to use its facilities and cooperate in the establishment of a well-developed and formulated plan which will promote the adoption or adaption of mining technologies through information sharing, technical assistance, training, and the promotion of linkages between R&D and technology users.



THE DEVELOPMENT OF REMOTE MINING SYSTEMS AND THE NRC CONTRIBUTION

National Research Council

In planning the future development of automated and remote mining systems it is useful from the outset to recognize that such systems contain major elements from four major areas:

1) Process knowledge
2) Sensors and instrumentation
3) Mining equipment with new control and communication capabilities
4) Communication, control systems and systems development.

Development in these four areas will require the coordinated effort of many groups and organizations. For example, process knowledge, and new developments in this area, will come primarily from those with knowledge and experience in mining engineering. Improvements in the control and communication capability of mining equipment will come primarily from the equipment suppliers. The National Research Council has an interest and capability in at least three of the above areas, together with a willingness to work with others.

The NRC capability, as a resource contributing to further development, is of three types: the research work of the laboratory divisions; the provision of development grants to industry through NRC's Industrial Research Assistance Programs (IRAP); and the provision of technical information, primarily through the Canada Institute for Scientific and Technical Information (CISTI), which is one of the largest resource centres for technical information in North America.

The Systems Laboratory of the Division of Mechanical Engineering has worked on mining systems problems for a number of years, particularly in the area of modelling and simulation. More than a dozen projects have been carried out over the past 15 years concerning specific systems level problems for specific plants and companies. Current work, in conjunction with the CANMET Coal Research Laboratory, is directed toward the development of a Decision Support System for surface mining. Productivity studies on mining operations have shown that considerable improvement should be possible by the application of this methodology.

The Instrumentation Coordination Office in the Division of Electrical Engineering has been available over many years to assist industry with sensor and measurement problems, which often require a multidisciplinary approach. Work in this division on sensors and instrumentation is now incorporated in the newly established Laboratory for Intelligent Systems, which has a mandate for the development of advanced robotics and intelligent systems.

Examination of the four component areas listed above for automated and remote mining systems clearly identifies the systems nature of the development effort required. Mining automation involves not only mechanization and local control of machinery but also monitoring, transmission, collection and analysis of performance data for use in overall operational decision-making. Hence, while increases in productivity of specific pieces of machinery can improve overall mining productivity, the associated benefits will be maximized only if the overall mining system functions efficiently, thereby maximizing machine utilization.

NRC is ready to play its part in further development, recognizing that many other organizations and contributors are also involved, each with their interest, capability and contribution.

NRC personnel have cooperated with CANMET personnel to write and present a technical report at the Annual General Meeting of the Canadian Institute of Mining and Metallurgy on May 11-15, 1986 at Montreal.

The paper is entitled: Recent Developments in Remote Mining Systems, and is authored by:

N. Burtnyk, J. Scrimgeour of the National Research Council,
J.E. Udd, J. Pathak of Mining Research Laboratories, CANMET

Although the paper cannot be presented at this workshop the abstract below indicates the contents of this technical report.

The development of mining methods and systems to reduce the effort required by the operator at the cutting face, and to improve operator safety, has a history as old as mining itself. Over many years, systems have evolved from those that were purely manual to some recent automation systems, referred to as remote mining, in which no human involvement is required directly at the cutting face during normal operations. By means of remote control, sensing and communications techniques, the operator is able to direct all essential operations in greater comfort and safety from a cabin or control room environment which eventually, if economically and technically feasible, may be located a great distance from the face, even at the surface.

Canada has been one of approximately 10 countries participating in the Joint Coordinating Forum on International Cooperation in Advanced Robotics (JCF), with NRC acting as the focal point for Canadian participation. The robotics forum is one of approximately twenty established in various fields, following agreement at the 1982 Versailles Economic Summit meeting, to encourage international cooperation in the development and application of science and technology.

In 1985, by discussion through the robotics forum and via the embassies of the participating countries, the USA proposed to establish an International Centre for Research and Development in Innovative Systems for Remote Mining.

The paper will review these events together with a plan for a Canadian program and participation. This will include review and discussion derived from a JCF sponsored workshop on Robotics in Mining held in Paris, May 21-22, 1985 and an International Symposium on Innovative Mining Systems held November 4-5, 1985 in the USA. A Canadian consultative workshop is also planned prior to April 1986 for the purpose of communication and planning by interested bodies in Canada, including operating mines, equipment suppliers, development centres and government.

DEVELOPMENT OF CONTINUOUS CUTTING MACHINES AND THE VARIABLES INFLUENCING THE 'CUTABILITY' OF SUDBURY AND OTHER HARDROCKS

Dr. D.E. Goldsack, Dr. G. Rubin, Dr. M. Leach, Dr. P. Singh,
Dr. R. James, Dr. P. Lindon, Mlle. R. Prud'homme

Laurentian University Hardrock Research Team

INTRODUCTION

The development of a continuous cutting machine capable of excavating Sudbury orebodies economically, would represent a significant advancement in mining technology since the rock types that host these ores are recognized as some of the most difficult to cut. The critical component of this machine will be its cutting tool. However, before this tool can be successfully designed, it is important to recognize that a fundamental understanding of the materials to be cut is first necessary.

Although much work has been published on the physical and chemical characterization of bulk rock material, not excluding Sudbury rock types, the reasons why some rocks offer more resistance to cutting action than others are still not thoroughly understood. We believe that a more advanced understanding of the problem will be found through a detailed examination of the properties of the phases that form these rocks and the way in which they are combined to form naturally occurring mineral assemblages. We conclude then that there is a need for building a data base consisting of the appropriate physical and chemical properties of the mineral phases and rock types that host the Sudbury ores, as well as those from elsewhere. Furthermore, there is also a need for a better understanding of the 'cutability' characteristics of these materials by developing simple models between cutting parameters and material properties.

Since a purely mechanical approach to the cutting of the Sudbury rock types using a continuous cutting machine has so far been unsuccessful, it would appear appropriate to evaluate the effects that additional energy inputs might have on rock fracturing, in order to improve the cutting characteristics of a continuous mining unit. At Laurentian University, research is now in progress to evaluate the effect that chemomechanical and ultrasonic energy sources have on rock fracturing.

CUTABILITY OF HARDROCKS

'Cutability' is a term that has only recently been applied to rock as the result of the growing trend toward continuous mining or 'continuous cutting' of rocks. Cutability is generally defined as a 'machinability index'. The striking feature here is that the definition of the term is as vague as the term itself. For this reason, it is necessary to assemble a database consisting of existing empirical cutability indices for hardrock, with particular reference to Sudbury rocks. These data will permit a definition of the major parameters that have been proposed as the determinants of cutability. Once assembled, the data base would serve as a reference tool which could be used in the development of a concept to explain the resistance of Sudbury and other rock to continuous cutting action.

The fact that cutability is akin to machinability implies the application of a continuous destructive action to the material to be cut. At present, hard-rock is removed in bùlk from the in situ mass by:

a) Combination of mechanical tools (to drill the holes) and explosives.

b) Mechanical tool alone.

Attempts are also being made to effectively dislodge the rock by the combination of mechanical and other energy input sources. It is obvious that the mechanical tool plays a crucial role in primary rock breakage and it is important to review the principles by which these tools induce rock fracture. In order to optimize the cutting process, it would be essential to:

a) Assess the resistance of the rocks to cutting.

b) Develop cutting models.

Rock can be cut by different types of mechanical action. This statement can be extended to say that different rock types will react differently to the same cutting action, depending on variables such as grain size, pore space, hardness, effective ultimate strength, thermal conductivity, etc. The movement of the crack tip in different rock types, after initiation of the crack, has been the object of much attention in terms of the factors that determine whether a crack will propagate through the actual grains or along intergranular boundaries. Many theories have been postulated to explain the mechanisms of rock breakage in terms of fracture propagation and the other characteristics of rock such as those mentioned above. Typical fracture patterns in Sudbury rocks caused by different cutting actions need to be studied in relation to the actual properties of the composite materials under the real conditions of temperature and pressure that the cutting tool experiences. Present mechanistic models of cutting do not address these factors.

MINERALOGICAL ASSEMBLAGES AND PROPERTIES OF SUDBURY ROCKS IN RELATION TO CUTABILITY PARAMETERS

Pyrrhotite, pentlandite and chalcopyrite are the principal sulphide minerals in the ores of the Sudbury Igneous Complex. The rocks that host these ores are classified as norite, gabbro, quartz diorite, granite, granite gneiss and greenstone. While some of these rock types are much more intimately associated with the ores than others, to liberate the metallic minerals from their environment it is necessary to be able to cut through all of these rock types as well as the sulphides themselves.

The silicate phases which form the major rock types mentioned above are plagioclase and alkali feldspar, hypersthene, augite, hornblende, quartz, biotite, and lesser amounts of epidote and chlorite. In order to determine why rocks formed of these minerals are so difficult to cut (and by this, we mean resistant to fracture/solution when exposed to a focussed energy input via mechanical/physiochemical systems), it is necessary to collect and evaluate the following types of data:

1) Knowledge of how the internal structure of each phase reacts to energy input and the order of magnitude (of energy) necessary to cause each compound to shatter:

Over the past two decades, there has been a steady accumulation of values of thermodynamic and mechanical properties of minerals and rocks. Some of these parameters have been correlated with empirical measures of the cutability of rocks such as hardness, etc. Two principal uses of these data, once accumulated as a data base, are foreseen.

First, a measure of the cohesive energy of individual minerals can be readily obtained from the thermomechanical properties, the coefficient of thermal expansion and the compressibility. The former is obtainable from density measurements and the latter from acoustic measurements. This cohesive energy can be related to the hardness and the surface energies of the material and thus to cutability.

In addition, simple mixture models can be utilized to study the effect of composition on this cohesive energy in order to compare observed cohesive energies of various rocks with their variable mineral content. The effect of grain size can be incorporated through surface energy effects.

Furthermore, the effect of temperature and pressure on the cutability or hardness of a particular rock can be estimated from the composition and thermal properties of the constituent minerals. Since it is known that mechanical cutters working on hardrock materials result in high temperatures and pressures being generated at the cutter-rock interface, and since the strength characteristics of rocks generally decrease with increasing temperature, then an understanding of the effect of these variables on these properties is critical to an understanding of any mechanism proposed for the cutting of the rock, be it mechanical alone, or mechanical plus other energy input. The influence of temperature on the rock-cutting process is very critical and warrants due consideration and will be dealt with in depth in subsequent phases of this study.

2) Hydrothermal reactions:

Since water is readily available in most mining areas, it is sensible to investigate the possible chemical reactions that could occur between the rock material and this fluid during the cutting process. (If such chemical reactions do occur, they may enhance the cutting performance of the mechanical tool through increased solubility in water, etc.) The thermodynamic data set indicated previously could be utilized to determine whether or not, under the pressure-temperature conditions of the cutting process, various chemical reactions with water will occur.

3) Sonic and ultrasonic studies:

The determination of the elastic moduli of hardrock and their dependence on stress, temperature, chemical environment, anisotropy and also on frequency will provide important information concerning the cutability of rock and the efficiency of the energy transfer from a cutting tool of a certain shape and of a certain velocity relative to the rock into the bulk of the rock. These moduli need to be determined over a wide range of frequencies by measuring the velocities of pressure and shear waves, also taking into account variations in the density of the rock material from one phase to another.

4) Influence of rock fabric on energy input required to break rock material:

Parameters such as grain size, shape of crystals forming the aggregate, and presence or absence of a preferred orientation (foliation) in the rock need to be evaluated and incorporated into the rock-breaking models.

The above mentioned effects, particularly the temperature, pressure and hydrothermal characteristics can be evaluated separately from the mechanical cutting effects and the combination of both effects could be considered as a chemomechanical cutting tool. Indeed, the chemical component of the cutting action can be enhanced once the chemical and physical properties of the material have been determined.

SUMMARY

In order to successfully evaluate the mechanisms of cutting actions for novel multifunctional cutting tools with Sudbury hardrocks, it has been emphasized that a sound physiochemical base for these materials needs first to be established. Such a data base for rock types of the Cambrian Shield is being accumulated at Laurentian University. Furthermore, a multidisciplinary team approach to this strategic problem with an emphasis on fundamental modelling and data gathering is being utilized. We believe that the synergistic interaction of the engineers with geochemists, physicists and chemists of this team will lead to a better understanding of the resistance of Sudbury hardrocks to cutting action. This understanding will, in turn, lead to a better appreciation of the variables that must be optimized to produce the most effective tool for continuous cutting of hardrock.

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PRESENTATION TO THE CANMET/MRL
AND OCRMT WORKSHOP ON MINING AUTOMATION

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Natural Sciences and Engineering Research Council of Canada

NSERC is the Natural Sciences and Engineering Research Council of Canada. It is a federal granting agency that channels over $300 million every year into research and the training of scientists and engineers. Its functions are to promote and assist research in the natural sciences and engineering and to encourage R&D links between universities and industry.

To put it in context, NSERC in 1984-85 received and distributed 10.5% of the total federal R&D dollars. It contributed 35% of the external R&D support to Canadian universities.

NSERC supports university-based research through a variety of programs which cover the whole range of the R&D effort. These are listed in Table 1 of this paper together with an illustration of the allocation to each. I will briefly discuss those programs that are most likely to be of interest to you.

The Operating Grants Program forms the core of NSERC's granting program with an annual budget of $144 million. Grants are awarded to university researchers according to the discipline in which they work, for example: computer science, mechanical engineering, earth sciences. The Operating Grants Program supports "free, discovery-oriented research" and a great deal of flexibility is allowed to the researcher to pursue whatever avenue he or she wishes in the context of the overall program. Generally speaking, this program covers the R of the R&D spectrum, although both basic and applied research are supported. The accent here is on scientific originality and innovation.

Targeted Research comprises two main programs: the Strategic Grants Program with a budget of $32 million and the University-Industry Program with a budget of about $10 million. The objective of the Strategic Grants Program is to provide support for the initiation or acceleration of substantial projects in certain areas of national concern. These areas are the following: biotechnology, communications and computers, energy, environmental toxicology, food and agriculture, industrial materials and processes, and oceans. There is also an open area that offers researchers an opportunity to address important problems in areas other than those specifically identified. The aim of the program is to enable researchers to make greater contributions toward the understanding or solutions of problems of national concern through specific applied research projects having potential for relatively short-term socio-economic benefits, or through more basic research designed to develop knowledge in areas of socio-economic importance. User interest in the proposed research is a crucial aspect although no financial involvement is required from industrial and/or government collaborators.

The areas of industrial materials and processes, communications and computers, and the open area are particularly well suited for research in robotics, mining engineering and mining automation.

The University-Industry Program, through its cooperative research and development grants, provides university researchers with an opportunity to conduct a wide range of R&D projects in collaboration with industry. Projects can range from a short-term endeavor to bring an advance in a university laboratory to commercialization, to longer-term research in a technology of direct interest to a company.

This program requires a financial commitment from the industrial partner; however, this commitment can take the form of dollars, human resources, services, minor equipment, supplies, or major equipment.

The University-Industry Program is quite flexible and can entertain any innovative proposal for the transfer of technology between the two sectors or for the sharing of facilities and training environments. The program includes various components such as Industrial Research Fellowships and Postgraduate Scholarships, NSERC Industrial Research Chairs aimed at developing new centres of competence in industrial research, shared equipment and facilities, and workshops and seminars.

NSERC's strength lies in its ability to respond effectively to funding needs across the whole R&D spectrum, its risk-taking ability, and its minimal administrative procedures.

As you may have heard, university research and training were featured in the February 26 budget speech. NSERC received a multi-year funding commitment from the government for a secure base of $311.6 million for each of the next 5 years. In addition, there will be an opportunity to increase this basic funding as the government will match, on a dollar-for-dollar basis, incremental private sector contributions received by NSERC to an annual maximum of 6% of the Council's previous budget. The aim is to improve R&D contacts between the business and university community, and enhance the application of Canadian scientific knowledge to our industrial needs. Mechanisms for implementing the private sector contribution are being developed and will be announced. A tax change will be made to ensure that the private sector participant will be entitled to research and development tax treatment.

NSERC is very interested in the identification of specific research topics in the general area of mining automation because Strategic Grants Selection Panels are in the process of identifying research niches that are of particular interest to the industrial sector. We also encourage the industrial participants here today to consult NRC's "Index and Guide to Robotics Research and Development in Canada" to identify university researchers whose work may be of interest to you and with whom you might collaborate.

TABLE 1

Natural Sciences and Engineering Research Council

(in Millions of Current Dollars)

ELEMENT	1984-85	%
Research Manpower Training	51.5	16.5
Discipline Research	144.3	46.3
Targeted Research	42.9	13.8
Equipment and Infrastructure	37.3	12.0
General Programs	24.5	7.9
Administration	11.0	3.5
Total Expenditures	311.5	

COMMENTS TO CANMET/MRL AND OCRMT WORKSHOP ON MINING AUTOMATION

J. Pathak, CANMET/MRL

Canada is well known around the world for its innovative mining methodology but it is not a commodity that can be exported to give financial benefits to the country. We are net importers of hardware required for production. It is the technology and hardware that earn foreign exchange, and not the methodology; although it might indirectly do so by lowering the production cost. The main drawback that has been stated by the manufacturing industry is that the Canadian market is not large enough for them to venture into this field. Sweden and Finland are examples of small countries that develop equipment not only for their own consumption, but also for export, and both of these countries have been extremely successful in this field. Canada has a huge deficit in comparison with these countries. Sweden exports 85 to 90% of its production. They have excellent test sites, as does Canada, but the Swedish equipment manufacturers have better testing arrangements with mine operators. They only sell proven equipment after intensive testing.

In 1982, CANMET undertook a bold step to initiate a study (contracted to Robertson Nickerson of Ottawa) to find out what the Canadian mining industry thinks about robotics in mines. The objective was not to perceive its applicability or to make a concrete proposal, but to initiate thinking processes on these lines. This report is well known to some members of this audience. The nature of hardrock mining is such that even to talk about robotics is inconceivable. Those knowledgeable in mining details are working at the mines, and their energies and abilities are directed at the day-to-day operations. Falling metal prices and demands will not permit any major improvements that do not give immediate and obvious payback. Fortunately, underground coal mining is now in a position to go to full automation and remote control mining because of the nature of coal deposits.

Although, previously, it was thought that the hardrock mining environment poses great difficulties for achieving full automation, remote mining or robotization at the face (stope), a flurry of activities in this area is now noticeable in many countries. Programmable drilling jumbos from Norway, ore-sorters from South Africa, and an automated rod handling DTH drill from Sweden, are a few examples. Some Canadian companies are also looking into 'out-of-sight' remote control of mobile equipment, an underground information system for better management of shifts, equipment operation and maintenance, personnel deployment and gathering of vital statistics for making day-to-day decisions at the first and second lines of management/supervisory levels.

Most of the techniques used in hardrock mining are cyclical processes and such processes are difficult to automate. Unpredictability of fragmentation hinders automation of loading and hauling muck. It is difficult and expensive, and sometimes even impossible, to design equipment to handle the wide range of sizes that are encountered in a cyclical operation of an underground hardrock mine. Automation alone, i.e., taking the person 'out of the loop' is not good enough. The process has to be optimized and that is where high-tech and microprocessor control application becomes a determining factor. These concepts are rather easier said than done in hardrock mining.

In some cases, it is not necessary that equipment or a system be designed to fit a mining method but rather the method itself has to be changed to suit the system. An example of this is VCR mining, which was designed to take advantage of DTH large blasthole drills and shaped charges. Blasting technology has not changed for decades, although it has been improved many times by refinement. To design an automated explosive loading system, I think the whole concept of packaging, handling, loading, detonation and utilization has to be changed. It has to be looked at as a 'system' and not as an individual blasting operation. With existing packing and detonating techniques, it is difficult to automate or robotize.

Although CANMET does not have a mandate to support equipment development, it has done so to a limited extent in the past. Certainly, some related R&D as regards the development of new technology, is within its objectives. Automation, high-tech application, and robotization must be directed toward improving safety, recovery and productivity.

It is expected that these will all have an influence on cost reduction. CANMET has a great interest in remote monitoring and control of ventilation (quality and quantity), compressed air, fresh water lines, whole pumping system (supply and drainage), weighing and identification of cars, weighing of skips, ore/waste flow, monitoring of remotely placed installations or equipment, gathering of mine statistics for shift bosses'/captains' reports (fully instrumented mine), etc. Because there are a large number of mines operating, all these developments should have the capability of retrofitting. New mines will not pose that much of a problem.

MEMORANDUM FROM THE CANMET COAL RESEARCH LABORATORIES

D.B. Stewart

With the current restraint on discretionary spending, CRL will be unable to attend the mining automation workshop. I do however have some comments on the subject which may be useful.

I believe in a stepwise approach to automation and see robotics as the goal or end product of a lengthy series of steps that must be duplicated for classes or categories of mining equipment. Some types of equipment - hoisting and raise-borers for example - are currently well down the automation path and are closer to robotic operation than other types of equipment.

It is useful to examine how we have progressed to automatic or semi-automatic operation. Using open-pit rotary drills as a example, the first step was the theoretical understanding of the rock breakage mechanism of tri-cone rotary bits. That understanding led to the development of field trials for data collection using sensors to measure the important variables identified through the theoretical understanding of the rock breakage mechanism. Not surprisingly, the field trials highlighted the fact that different operators have different skill levels. The trials also demonstrated that bit pressure was a strong candidate for automatic control because poor operators tended to reduce bit pressure (thereby reducing penetration rate) in order to avoid overloading the bit and damaging the cone bearings. The trials emphasized the need for higher rotational speeds and better chip bailing velocities. The semi-automatic drill has now been available for at least 10 years and the end result has been better drill performance through automatic control of bit pressure coupled with higher rotational speeds and chip bailing capability. Other improvements in rotary drilling equipment have also occurred but automatic bit pressure remains an important contributor to drilling performance.

In general I would favour a similar process for other types of mining equipment:

1) Define practically and theoretically what the machine is expected to do and what measurable variables could be significant.

2) Develop appropriate sensors and data collection methods.

3) Conduct field trials of sensor-equipped machines.

4) Identify significant variables that are candidates for automatic control (select variables that can be sensed and controlled with emphasis on those with which operators encounter trouble).

5) Conduct field trials with equipment that is semi-automatic, but has manual override, to give feedback loop system development a chance to be proven in actual field conditions.

6) Consider/develop/field test fully automatic machines with operators.

7) Eliminate the operator from 6.

(Obviously steps 6 and 7 would involve a number of steps not identified here.)

One of the attractions of this phased approach would be that industry would quickly obtain pertinent data on actual machine performance. These data would lead to refinement by industry (both mining and machinery sectors) of existing equipment to improve performance and reduce costs.

For example, in the mid 1970's I was involved in a project conducted by the Canadian Explosive Atmospheres Laboratory (CEAL) that measured LHD diesel engine load cycles at Inco Ltd. operations. That field project identified a major hydraulic problem with the steering valve on the machine that we tested, and this led to the Inco-Jarvis Clarke pioneered use of stick steering that has proven simpler to use and maintain, is safer and has reduced parasitic hydraulic losses (i.e., more engine power available to do real work).

One of the more interesting tasks will be to identify with industry the candidate types of machinery for automation consideration. Sensor development could also prove difficult, however I believe that most, if not all, of the required sensors exist in the automotive and aviation fields. In terms of CANMET expertise the real problem may be the identification of individuals who can do the field work. Such people must understand the details of mechanical equipment design, be able to think and act as equipment operators, understand the constraints of mining, and be able to think on their feet so that field trials are successful (i.e., be able to modify sensors and trial protocol on the fly, to meet changing conditions and requirements).

Skilled machine operators use all five senses to control their machine. The difficulty in providing mechanical sensors to duplicate such a complex signal receptor cannot be overestimated. Diamond drills are a good example. A skilled diamond driller spends much of the time listening to drill string noise and feeling for vibration. If really good, he or she can maintain high rates of drilling by operating close to the point where the bit would burn.

AUTOMATION TECHNOLOGY DEVELOPMENT FOR THE CANADIAN MINING INDUSTRY

Malcolm Scoble, McGill University

INTRODUCTION

This paper aims to contribute to developing an outline strategy for research and development to automate Canadian mines. This workshop has been motivated by the sequence of developments arising from the 1982 Versailles Economic Summit and the subsequent establishment of the working group on advanced robotics, the Joint Coordinating Forum on International Cooperation in Advanced Robotics (JCFAR). The JCFAR has identified the areas of robotics technology that are appropriate for government involvement as those which will lead to removing people from harsh, difficult or dangerous environments (1). Such environments exist in the Canadian mining industry but only in a limited sense. The industry is demonstrably safety conscious and it is suggested that this has focussed as much interest in robotics technology as have the concerns for productivity and economics. The recent trough in mineral commodity prices and growing international competition has emphasized the need to improve productivity and viability through the development of innovative equipment and methods. The growing awareness of recent, dramatic advances in robotics technology should not cloud the more basic issue that mines require to tread the path of mechanization, monitoring and then automation. Reference to the experience of overseas mining industries shows that success in the mining environment comes from this incremental approach and requires considerable time, funding and determination. In the context of our industry, robotics should be classed as a form of advanced automation and only a component of the wider subset of R&D areas which could include mechanization, monitoring and control systems, materials science and mining methods. An important point of relevance to the Canadian industry is that progress in equipment development can be shown clearly to spark innovative mining methods with significant impact on productivity.

A case can be made that Canada should be more concerned with underground than surface mining technology. Traditionally surface mining has employed a higher degree of mechanization than underground. The equipment manufacturers have successfully driven the mechanization process and this promises the approach of automation with the advent of continuous mining systems. Reference is given henceforth only to the more harsh and constrained underground environment.

This paper reviews aspects of mining technology development in the U.K. and South Africa. This is aimed to provide some insight into the requirements for a successful automation strategy as revealed by the experiences of their mining industries. Then the format of the Canadian industry, including its manufacturing base, and its R&D capability will be considered. Reference is given to Canada's research institutions, including its universities. Their role in the development of automation and robotic technology will be considered. Recent initiatives taken at McGill will be related to mining applications. Finally, in summary form, suggestions will be proposed as to the appropriate strategy to be adopted for the advancement toward automation in the Canadian mining industry.

OVERSEAS EXPERIENCES IN MINE AUTOMATION

The need to promote mine mechanization through centralized R&D became apparent in both the U.K. coal and South African gold industries several years ago. The two experience the benefit of closer liaison within their respective industries due to the common production and mining methods, together with a reduced variety and less dispersion of mining units, in contrast to Canada. Both industries were conscious of their reliance on low productivity, labour intensive mining methods, and their significant roles in the national economy. Both employ essentially similar longwall working methods in geometrically comparable mineral deposits - thin, tabular deposits at commonly gentle inclinations. Geology in both cases gave rise to constrained space and harsh working environments with ground control and environmental engineering challenges. The primary factor that has above all determined the degree of success each has achieved, after considerable efforts at mechanization, is the nature of the rock masses in which mining is undertaken. Essentially this represents a contrast between weak to medium strength coal measures and very strong, abrasive Precambrian rocks. The rock mass has significantly governed the mechanization of rock breakage and transport processes.

It is of interest to briefly examine the strategy that each of these two mining industries has adopted and the factors that have governed their respective degrees of success at mechanization.

U.K. Coal Mining

Coal mining in the U.K. has been a nationalized industry since 1947. In 1983-84, it had a turnover of £2.46 billion ($4.92 billion CAN), 170 underground mines and a total of 246,000 employees (2). Overall output in underground mines was 2.43 tonnes per personshift with 22 fatal accidents. Over the last 25 years, a major effort has been aimed at mechanization and automation to improve productivity and safety, with strong governmental support.

In 1983-84, approximately 1% of turnover was invested in R&D. Mining had $32 million devoted specifically to it, using 500 engineers/scientists and 125 technicians. The industry has benefited from a coordinated R&D strategy undertaken primarily by its centralized Mining Research and Development Establishment (MRDE).

MRDE has its own Automation and Mechanization Division which in particular has made significant advances in coalface automation and tunnelling. Primitive robotic machines have been successfully introduced into operations based on real-time systems. Efforts at the coalface have concentrated on guidance systems for the coalwinning machine to potentially double productivity, reduce dilution, and improve ground control and availability. Vertical machine guidance systems developed employ either natural radiation sensing of roof position or tactile pick force sensing of machine seam location. Horizontal machine guidance to ensure face straightness and advance measurement has been achieved with three alternative systems based on optical surveying, cord transducer and ultrasonic measuring techniques (3). Such guidance systems are seen to lead ultimately to a fully automated system for coal cutting, armoured face conveyor and roof supports at the coalface. Efforts at tunnelling by MRDE have seen developments in full-face, shield roadheader type machines with segmented concrete support; high pressure water jet assistance; remote controlled drilling; and computer controlled drilling (4). Automation of roadheader tunnelling machines is well advanced together with development of machine monitoring systems. The latter are aimed to monitor machine condition and performance, enabling maintenance in non-production time.

Data monitored from such various automation schemes are transmitted to mine surface centralized sites together with data from mine environmental monitoring for management. The NCB has sought to mechanize - monitor - automate existing traditional longwall methods in an incremental manner. To date, this has entailed around 5 years to go from concept to prototype, with a further 5 years to proceed from prototype to proven production verification. Systems in future development are aimed to be self-diagnostic, more reliable and less dependent on operators who will function in a remote supervisory role. The surface computers promise to play a growing role in data collection and analysis to develop Artificial Intelligence techniques and algorithms for subsequent use underground. Fully integrated coalface systems and automated tunnelling machines are development objectives for the next decade and will represent advanced robotic systems.

It is of interest that the traditional longwall method of mining is currently envisaged as appropriate for the long term, but that an In-Seam Miner system is being developed and evaluated as a potential means of adopting alternative methods of coal production.

The NCB and MRDE works closely with the strong U.K. manufacturing sector in prototype and production equipment development. MRDE also has had considerable contact with U.K. universities, primarily in the form of contract research and postgraduate student support. The association of the centralized MRDE with manufacturing industry and universities has represented an effective alliance of significant benefit to each party.

South African Gold Mining

The gold mining industry in South Africa in 1984 employed over 500,000 persons to product .68 million kg of fine gold realizing over R 11 billion ($11 billion CAN) in proceeds (5). R&D for the industry is primarily undertaken by the centralized Research Organization of the Chamber of Mines of South Africa, which works in close collaboration with its member mines. The Chamber is supported by its 103 mining industry member corporations, 40 of whom are involved in gold mining. In 1984, the Chamber's Research Organization expended R 33.2 million ($33 million CAN) on gold mining research (6). Research sponsored by the gold producers was classified under the areas of Gold Distribution and Extraction, Underground Environment, Human, Rock Pressure, Stoping and Special Research. The Organization employed 587 staff in 1984. Much of the research effort was orientated toward mechanization of what are labour-intensive mining operations in a very difficult environment. Problems arise from the constrained space afforded in typical stopes, great depths and high rock pressures, very strong and abrasive rock types and high temperature and humidity working conditions. For many years, the Chamber has been directed by the industry to address these problem areas and increase mechanization. The significant long-term investment in this centralized facility has seen great advances made in improved efficiency and environment.

Little attention appears as yet to have been given to robotics in this environment, in which mechanization itself faces severe obstacles. Major areas of recent research interest that carry significant amounts of innovative work, however, are as follows: implementation of hydraulic rock-drilling in production; mucking of ore in stopes using water jets; underground milling; underground waste sorting; underground experimental backfill plant; generating hydroelectric power at shaft bottom for cooling deep mines and powering machinery; and conveying ice underground for mine cooling. The Chamber links very closely with its member mines and has a direct involvement in field trials and prototype evaluation in the underground environment. The strategies being adopted to improve stoping productivity are: improving individual constituents of the conventional stoping method; mechanizing the most critical activities in stopes mined by blasting; and developing mechanization to enable stoping without blasting, which is considered by the Chamber to be the most promising. Integrated mechanized systems are being sought, similar in concept to longwall coalface systems, employing a continuous impact hammer mining machine, mounted and moving along a guiderail, linked to a rockhandling conveyor.

The overall direction of the research program is maintained by a Research Advisory Committee comprising three senior Chamber executives and fourteen members representing member mining companies. The Organization offers to Chamber members a range of specialist and consultative services on a contractual basis to support the implementation of developments arising from research. Services emphasize technology transfer through seminars and publications.

THE CANADIAN ENVIRONMENT

The Mining Industry and Applications

During 1984, the value of mining production in Canada rose 17.4% to $14.9 billion, representing, on a per capita basis, the world's leading mineral-producing country as well as the world's largest exporter of minerals (7). The industry employed 107,975 persons in its 282 mines, over 80% of whom were in hardrock.

A survey of the industry by Robertson Nickerson Ltd. in 1982 identified potential applications for robotics and remote control systems (8). The report highlighted that the level of robotics awareness in the industry was in the infancy stages. The greatest potential for robotic applications was identified in underground mining. Short-term levels of robotization were suggested by industry for: drilling, explosives handling, ore removal, ground conditioning, raise boring and continuous miners. Long-term robotization was seen to involve telechirics and continuous mechanical mining technologies. A point of interest was that new technology developments may totally change the current direction of mine automation. This point is relevant when you consider that in the underground soft-rock environment, e.g., coal or potash, the rock breakage and transport machinery for continuous mining already exists. In hardrock mining, however, the key technological breakthrough in these areas has not yet been made to enable continuous mining. When it occurs, it may well revolutionize the working methods themselves. It should not, on the other hand, deter research from looking at more innovative designs of mining methods using conventional equipment over the short term. The geological setting of Canadian hardrock mines provides the opportunity to develop innovative extraction methods, based on established or emerging technology, which in themselves could radically improve productivity and cost-effectiveness. It should also be recognized that extraction method development involves consideration of factors of influence additional to the electrical and mechanical engineering aspects related to equipment. Environmental engineering, ground control and mineral economics also exert important influences over design effectiveness. This underlies the need to develop with a truly multidisciplinary approach.

The mining equipment manufacturers serving the Canadian industry are predominantly multinationals, with their research laboratories outside of Canada. Over 70% of the branch plants are straight assembly plants with the extent of their R&D being modification of a machine (7). In 1980, the industry spent over $1.2 billion on machinery, equipment and parts. In contrast, the European mining industries benefit from a stronger, more closely associated equipment manufacturing base. Some Canadian mining companies appear willing to initiate equipment development based upon their own needs which hopefully will give rise to the evolution of a stronger indigenous manufacturing sector. The formation of HDRK and its support of more capital-intensive R&D, as well as the Ontario Centre for Resource Machinery Technology, are also encouraging signs of growing initiatives to strive for mechanization and automation.

Government, Industrial and University R&D Agencies

At the initiative of the National Research Council, a guide and index to robotics R&D in Canada was prepared in 1985 under contract by the Robotics and Automation Laboratory, Department of Mechanical Engineering, University of Toronto and the Ontario Robotics Centre (8). This work was based on a survey response from 23 government/industrial and 48 educational units with robotics R&D interests. The findings of the survey team was that a tremendous interest exists in this R&D area; several centres have a strong history of prior activity; and many more centres were in an early building phase. The quantity and quality of work in general was found to be impressive. The level of funding, except for some selected centres, was not found to be adequate. The mining industry would therefore seem to have available a good resource within this array of existing agencies in Canada.

Recently in the Faculty of Engineering at McGill University, an interdisciplinary Centre for Research into Intelligent Machines has been formed. This is based upon well-established computer vision and robotics researchers, primarily from electrical and mechanical engineering backgrounds. No mining engineering school internationally has to date established any significant research effort in underground mine automation, perhaps with the exception of the Colorado School of Mines, with its research into excavation engineering and water jet technology. A criticism that could be levelled at Canadian mining schools, as with their counterparts worldwide, is that traditionally they have not directed adequate attention to mine mechanization. Engineering research in general however is becoming increasingly multidisciplinary. In Mining Engineering at McGill, we have been seeking over the past several months a Professor in Mine Automation. The possibility of finding an experienced researcher in this field with mining experience has, not to our surprise, proved to be difficult. The intention of this appointment is to create a research group in mine automation that will interact with the above Faculty Centre at McGill as well as undertake collaborative R&D with industry. Potential application areas for R&D in the short term by such university efforts could be, for example: development and application of monitoring and control to mining systems, sensor development, and application of video information processing. University-based research is probably most suitably aimed at longer term objectives in areas such as robot vision and the creation of intelligent machines functioning on the basis of sensory inputs. One further important R&D application area of relevance to automation is that of materials science. Our department at McGill was recently awarded funding to initiate a research program in ceramics engineering. Ceramics are a good example of how new materials can revolutionize equipment construction and performance, offering superior strength, lightness, hardness, corrosion and shock resistance to conventional materials.

AUTOMATION TECHNOLOGY DEVELOPMENT

The Canadian mining industry with its large number of mining operations, geographically dispersed with a wide range of geological environments presents a significant challenge to the creation of an overall strategy for the development of automation technology.

The development of advanced automation and robotics technology for the mining industry should be achieved by the joint collaborative association of mining companies, equipment manufacturers and researchers (government, industrial and academic institutes). Long-term goals and priorities and procedures need to be clearly defined to achieve this.

EMR/CANMET, with the assistance of NRC and provincial agencies such as OCRMT, should continue the role of promoting an awareness of technology developments within industry. In a similar vein, the researchers require to be informed as to the needs of industry, together with the nature of its application environments.

EMR/CANMET should continue to represent the interests of the industry by evaluating any opportunities for international collaboration. The USA, through recent initiatives taken by its NSF, MIT/Penn. State and ASME, appears to be demonstrating a determination currently to host a North American centre of excellence in Innovative Excavation Equipment and Systems.

Experience in the implementation of automation technology in overseas mining industries indicates that shifts in technology should be incremental and not radical. Progressive development (mechanization, monitoring, automation and robotics) would appear to offer optimum chances of success in mining. This experience also indicates the prolonged time span between conception and implementation that can exist in reality, and the need for clear and coordinated long-range planning.

Attempts should be made to ensure that developments in automation technology give rise to a stronger national equipment manufacturing sector.

Academic research institutes should be nurtured and encouraged to continue their fundamental research as well as to undertake more applied research of direct relevance to the mining industry. Multidisciplinary centres of research excellence should be supported and interfaced with industry. Post-secondary educators should be encouraged to equip the industry engineers of the future with the appropriate skills to guide the advance toward automation.

The thrust of the advance toward mine automation will logically be driven by the handful of large mining companies in Canada. Increasing initiative by these companies is already becoming evident. The significance to the industry of smaller-scale mining should be recognized, however, together with its need also to remain productive and competitive.

CONCLUSION

The views expressed in this paper are those of a mining engineer working in an academic environment. My primary concern is that university research should be of high quality and relevance, as well as timely to industry, and that an appropriate mechanism exists to interface with the industry's practising engineers. University research has traditionally tended to be underutilized in Canada. Automation technology is a field where this should not arise in the future.

Reference to overseas mining industries demonstrates that successful automation will require a very large commitment in funding, personnel and time in a carefully planned and monitored strategy. This should involve mines, manufacturers and researchers in close collaborative association.

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ORGANISÉ PAR LE CANMET/LRM ET L'OCRMT

Hôtel Northbury
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APPENDIX 1

Dr. J.E. Udd, Director, Mining Research Laboratories, CANMET, presented the following paper at a meeting on international cooperation in research applied to automated mining and tunnelling held in Cambridge, Massachusetts on November 6, 1985.

The report is one in a series of Mineral Research Program reports and is identified by the CANMET division report number: MRP/MRL 85-125 (OP).

INTERNATIONAL COOPERATION IN RESEARCH APPLIED TO AUTOMATED MINING AND TUNNELLING - A CANADIAN POSITION AND PROPOSED ACTION PLAN

John E. Udd*

SYNOPSIS

At a meeting of the Advanced Robotics Working Group, in London, England, in May 1985, the representatives from the United States discussed a proposal for the formation of an International Centre for Research Applied to Automated Mining and Tunnelling. It was proposed, by the U.S. National Science Foundation (Addendum A), that the Centre be supported by participation and financial contributions from those countries that would be interested. Responses to the proposal were subsequently requested from the various countries - by formal requests through Embassy contacts and also through the delegates attending the May meeting.

The Massachusetts Institute of Technology (MIT) has proposed that the Centre be located on its campus in Cambridge, Massachusetts.

Because the proposed focus of the Centre is to be advanced mining technology, the Mining Research Laboratories (MRL) of the Canada Centre for Mineral and Energy Technology (CANMET) were requested to study the issue and prepare a Canadian response.

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BACKGROUND

At the Versailles Economic Summit meeting, in 1982, about 20 areas of technology were identified for future international cooperation. Advanced Robotics was one of these.

Following the agreement reached at the Summit, a working group was established. That group presented a proposal for international cooperation which was accepted at the Williamsburg Summit, approximately a year later. Subsequently, the Joint Coordinating Forum on International Cooperation in Advanced Robotics was established. With Japan and France as co-leaders, the other countries participating as members in the Forum are: Austria, Canada, Germany, Italy, United Kingdom, and the United States of America. The Commission of European Communities, the Netherlands, and Norway participate as observers.

The Joint Coordinating Forum has met on four occasions since its establishment. The most recent of these was on May 23, 1985, in London, England.

As a result of the meetings, the attention of the Advanced Robotics Forum has become increasingly directed toward specific areas of potential applications. At the very beginning, it was recognized (Addendum B), that the areas of robotics technology appropriate for government involvement are those that will lead to removing people from harsh, difficult, or dangerous environments. Specific areas that have been identified include: space, oceans, nuclear, mining, agriculture, civil engineering, plant maintenance, firefighting, and rescue operations. Directed attention is now being focussed on potential mining applications.

This attention results, in part, from the interest of the U.S. National Science Foundation in establishing an "International Centre for Research and Development in Innovative Systems of Remote Mining" in the USA, (Appendix A). In the words of Dr. Nam Suh, the Assistant Director of Engineering for NSF, "To initiate activity, NSF is interested in formalizing a major cooperative effort directed toward research in the field of robotics in tunnelling, mining, and innovative mining systems". It was suggested that the Centre be funded by the governments of the participating nations for a 5-year period, after which the Centre would be expected to be self-sustaining, through an industrial support base - which would be developed during the initial period.

The National Research Council (NRC) is acting as coordinator for Canadian participation in international programs in advanced robotics. With the focussing of interest on potential mining applications, the involvement of the Mining Research Laboratories of CANMET has been requested by NRC and the Department of External Affairs. MRL is the vehicle for the delivery of hardrock and nonhydrocarbon mining research within the structure of the Canadian federal government. Coal mining research is performed through a sister Division, the Coal Research Laboratories (CRL), with headquarters in Devon, Alberta. The views below represent the opinions of MRL, noting that CRL will be involved as further information concerning the U.S. proposal is received.

A CAPSULE VIEW OF THE CANADIAN MINING INDUSTRY

The Canadian mining industry is vast and diverse, and involves the exploitation of most of the better known mineral commodities. Canada is among the world's leading producers of copper, nickel, gold, silver, uranium, lead, zinc, and asbestos. Canada is an important producer of many other mineral commodities including iron ore, coal, oil and natural gas, the rare earth metals, and precious metals in the platinum group.

Because of its diversity, it is impossible to make simple statements that reflect the technological needs of the entire industry. With over 280 underground and open pit mines in both hard and "soft" rocks, it can be appreciated that there must be vast differences between the needs of individual operators. To a great extent, the requirements will be very site-specific.

To illustrate this point, coal mining usually involves the extraction of mineral from flat or gently dipping tabular seams. Hardrock mining, on the other hand, often takes place in irregular, near-vertical, and massive deposits. Because of geometrical factors, coal mines are more suitable for extensive mechanization.

In addition, technical innovations in the industry result most often from the work of the larger organizations, which may have both the staff capabilities and the financial resources that are vitally necessary. Smaller organizations, without R&D capabilities, are most often users rather than developers of technology. The Canadian industry contains a mix of both large and small operations, with the distribution being almost equally divided.

Another feature of the industry is that it is also very conservative. With the emphasis being on production and profitability, this is hardly surprising. No operator will stake the viability of the enterprise on untried and unproven technology. The risks are far too great, especially in the depressed metal markets of today, when, for many operators, the goal is simply survival.

In spite of the above statement, there is probably no operator that is not seeking the technical advances that will both reduce the costs of production and improve worker safety. The point is that, in order to be accepted, shifts in technology must be incremental and progressive. Radical shifts, unless proven, will almost certainly be rejected immediately.

Finally, mention must be made of the working environments and worker health and safety in Canadian mines. For, far from the common public image, there are few places into which workers cannot be sent without great confidence in their safety. Provincial governments, with whom the responsibilities for these matters rest, have been leaders in the enactment of progressive legislation. At present, in many jurisdictions, any worker has the right to refuse to enter any working place which he or she considers to be unsafe. Instances of such refusals are rare. Equally, because of legal responsibilities, any operator will close a mine working, either temporarily or permanently, rather than expose workers to risks that are known to be exceptionally severe.

Even though mining, and especially underground mining, is a tough occupation, it is not so dangerous, except in a few rare instances, as to necessitate considering the replacement of the workforce by robots. A determined move into robotics at this time would be viewed by the industry as a radical shift.

AN OVERVIEW OF CANADIAN MINING TECHNOLOGY IN AN INTERNATIONAL CONTEXT

In an international setting, Canadians are not known as developers of mining equipment and machinery but, rather, as innovators in mining methodology. The large-scale, low-cost, high-productivity mining techniques that have been developed in Canada are known and emulated throughout the world. The Vertical Crater Retreat (VCR) and Vertical Retreat Method (VRM), in which open pit blasting technology was modified to suit underground conditions, are perhaps the best-known more recent advances.

Other noteworthy contributions have included: the post pillar mining methods of Falconbridge; the pillar removal techniques used at Cominco's Sullivan Mine; the large-scale methods developed by Inco; the backfilling practices at Kidd Creek Mines and Noranda; the back-analytical pillar stability work done at Elliot Lake; and, in open pit practice, the Pit Slope Manual (in several volumes) developed by CANMET. Canada is a world leader in the development of hardrock mining methodology.

Canada is not known, however, as a developer of mining machinery. For that, much of the credit belongs to the European countries including the United Kingdom. With the exception of developments in the Scandinavian countries, however, most of the innovations have been related to either coal or softrock mining. Britain and West Germany are known for the highly mechanized coal shearers and roadheaders that they have developed, respectively. Sweden and Finland are best known for the advances that have been made in highly automated drilling raise boring technology. Their equipment is sold throughout the world, with a lot of it being destined for Canadian mines.

A conclusion that may be reached very easily is that each of the major mining countries has become known for a particular and highly specialized indigenous technology.

One of the functions of any international centre, then, should be to act as a focal point for the collection and dissemination of technological information. For purposes of credibility, however, any such centre must either be affiliated with an institution that is world-recognized for its contribution to the mining industry, or, alternatively, located at a place that is recognized as a major centre of mining activity. These elements are considered to be critical if an industrial support base is to be established.

PERCEIVED CANADIAN NEEDS FOR TECHNOLOGICAL INNOVATION

At present, there is no national consensus on the needs of the Canadian mining industry for technological innovation. With the emergence of interest in an international centre, however, we are planning to assess those needs in the near future through a workshop to which representatives of all of the key sectors will be invited. In the meantime, the thoughts expressed in this paper must be considered very preliminary. No doubt more precise needs will be identified as a result of the discussions that will soon take place.

Nonetheless, because the industry is modern and well equipped by international standards, and also conservative, it is certain that only an incremental approach will be favoured. A major shift toward robotics research would not be seen by the industry as addressing the most urgent present needs and would probably elicit little support.

On the other hand, there is no doubt that there would be much support for work directed toward improving mining equipment. There are still many opportunities to increase the extent to which mining operations are mechanized. Additionally, the extent to which mining equipment is automated is very small by modern industrial standards. The potential for achieving improved operational efficiency through the introduction of automated equipment is nothing less than vast.

In our opinion, then, both mechanization and automation probably offer better returns on investments than robotization. Government research in support of industrial needs, for the present, should be concentrated into means of achieving greater industrial efficiency. The development of robots is definitely a secondary, or even tertiary, priority at the moment.

There are, however, rare instances in which needs are more pressing than has been indicated. Existing technology, for example, may not be suitable for the extraction of recently discovered high-grade uranium deposits. Should it be found that the levels of radiation are sufficiently high as to preclude the efficient use of humans it is certain that the deposits will remain unmined unless an alternative technology can be found. In such cases, robotization may well be the only answer.

CANMET'S REACTION TO THE U.S. PROPOSAL

With all of the previously mentioned factors in mind, our reaction to the NSF proposal is as follows:

1) There is a need for a clearing-house for the exchange of information relating to technological innovation in mining equipment.

2) There is also a need for long-term research into the potential applications for industrial robots. The most acute short-term needs, however, are for increased mechanization and automation, with remote operation of equipment as an objective. Sensing devices are a prerequisite to the development of remote mining systems, and are included in these needs. Robotics research is of lesser priority at present.

3) Given this, the proposal to establish an International Centre should be encouraged.

4) Recognizing limited resources, however, an international working group, existing for the purpose of collecting,

exchanging, and disseminating technical information might be better suited to present circumstances. Such a working group should include representation from the mining knowledge centres in the participating countries.

5) It is essential that any focus of this effort must be such as to attract credibility from the mining industry and the knowledge centres involved. To do otherwise virtually guarantees that it will not be possible to establish an industrial support base.

6) CANMET would willingly participate in a working group. In order to do so, however, it would be necessary to enter into a formal 'Memorandum of Understanding' in that respect. At present, under an umbrella Cooperative Agreement, there are two such MOU's to which both CANMET and the United States Bureau of Mines (USBM) are parties. It is believed that arrangements could be made for another, in the general area of Mining Equipment Technology.

7) CANMET, however, is not able to contribute financially to a foreign centre. Because there are many unfilled needs of researchers in Canada for funds, the consequences of doing so would be severe. As outlined in the actions proposed below, however, an MOU would make exchanges of people, information, and technology possible.

Actions Proposed for CANMET:

1) Should a decision be made to form a working group or an International Centre in the United States of America, Canada, through CANMET, is prepared to collaborate in the form of an exchange of technology, information, data, and scholars. Arrangements could also be made for test sites and industrial cooperation in Canada.

2) CANMET believes that the USBM is the governmental focal point in the United States for international research projects in mining. We also believe that agreements between knowledgeable specialists at the government level are necessary before actual exchanges can take place. Given that there are presently Memoranda of Understanding in effect between CANMET and the USBM, on the specific topics of 'Wire Rope and Hoisting Technology' and 'Diesel Emissions', we would be prepared to begin discussions for another in the area of 'Mining Robotics and Automation'. We are prepared to proceed at once in this respect.

3) Because there is no well-defined national consensus on the present needs for robotics, we will be proceeding with a Canadian consultative workshop with industry and others in the next few months. The workshop will be co-sponsored by CANMET/MRL and the Ontario Centre for Resource Machinery

Technology (OCRMT). The outcome will alert the Canadian industry to these international developments, and provide a basis for understanding Canadian industry needs. The Proceedings will be published and will be available to all interested parties.

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Before writing this position paper, discussions were held with Mr. John Wilson, the Director of Technology Development of OCRMT. We are grateful for his interest and contributions of suggestions and ideas.

ADDENDUM A

Remarks by Dr. Nam P. Suh
Assistant Director for Engineering
National Science Foundation, USA
May 23, 1985

The Joint Coordinating Forum on International Cooperation in Advanced Robotics held its Fourth Meeting on May 23, 1985 in London, England. This Working Group on Advanced Robotics is one of the activities of the Economic Summit Working Group on Technology, Growth, and Employment. Dr. Nam P. Suh, Assistant Director for Engineering at the National Science Foundation, addressed the meeting and presented the following information:

The National Science Foundation has been actively engaged in international activities relating to science and engineering research for many years. Recently, a decision has been made to expand this activity and increase support of international cooperation in basic research that can benefit all free nations of the world and the people of the world. To implement this expanded role, NSF plans to strengthen its activities that are designed to fulfill bilateral international agreements and multinational treaty agreements in which the United States is a party. Simultaneously, NSF is increasing its support for robotics research through many of the existing Programs in the Engineering Directorate.

In reviewing the activities of the Advanced Robotics Working Group since its establishment by the Heads of State at Versailles in June 1982, I believe progress has been made in the identification of the required contribution of research and development to economic growth and employment, and the activities directed toward advancing the fundamental knowledge base in robotics and intelligent machines. However, to fulfill the spirit and goals of the Versailles Agreement, the National Science Foundation believes that the Advanced Robotics Joint Coordinating Forum should concentrate on a few key problem areas. One such area is the use of robots and other advanced technologies in the field of remote mining and tunnelling. To initiate activity, NSF is interested in formalizing a major cooperative effort directed toward research in the field of robotics in tunnelling, mining, and innovative mining systems.

The importance of this problem, in the context of societal needs and the quality of life for people engaged in these hazardous activities, cannot be overemphasized. The loss of lives and other human costs of mining and tunnelling has been recognized as an ongoing historical problem. Solutions to the safety problem, derived from evolutionary improvements in current technology, are complex and generally lead to reduced productivity. To further complicate and exacerbate the problem, the need for natural resources keeps increasing. In the 21st century, the increasing world population and the desire for an improved standard of living in the less-developed countries, coupled with the inevitable depletion of easily obtainable minerals will necessitate more and more hazardous operations.

Advanced technology is a possible solution that must be explored to benefit the peoples of the world. However, the research and development costs will be very high and the task is difficult. It is unrealistic to expect industry to bear the entire cost nor should one country be expected to pay the entire cost. Cooperation and collaboration by the nations represented in this Forum appears to be appropriate for both the technical problem and the spirit of the Versailles Agreement.

The advanced technology needed for progress to be made must be interdisciplinary and utilize a systems approach from conception to the development of specific technologies. To support the effort, research is needed in sensing techniques, modern control methods, new materials, advanced computing techniques, artificial intelligence, communications, and systems theory. This research coupled with modelling, systems simulation, and technology transfer will ultimately lead to more efficient and safer operations in tunnelling and mining.

In summary, the United States proposes for the consideration of the nations participating (and the observer nations) in the Advanced Robotics Working Group the following:

a) The National Science Foundation is prepared to establish an "International Centre for Research and Development in Innovative Systems of Remote Mining".

b) The purpose or objectives of this proposed Centre will be to develop the technologies and the systematic approach needed to achieve remote mining and tunnelling and to coordinate the R&D efforts of the participating international community.

c) Funding for the Centre will be derived from the governments of the participating nations for a period of 5 years, during which time the Centre must establish an industrial support base and become self-sustaining.

d) As a precursor, the NSF is planning to establish, as part of an on-going program of University/Industry Cooperative Research Centres, an R&D Centre in Remote Mining. It is anticipated that this Centre will encourage international participation.

The United States requests consideration of this proposal as rapidly as possible and expressions of interest from those countries wishing to participate in this major new initiative. It is understood that further discussions are required to generate a detailed plan and cost analysis. It is expected that a meeting of the interested countries will take place within the next three months for planning purposes.

ADDENDUM B

Joint Coordinating Forum on International Cooperation in Advanced Robotics

NRC is acting as the focal or coordination point for Canadian participation in an international program for cooperation in advanced robotics which results from agreements reached between countries represented at the 1982 Versailles Economic Summit meeting. The advanced robotics topic is one of approximately twenty technologies that have been organized for cooperation.

Recognizing that the industrial sectors in the countries represented are increasingly developing and utilizing robots, and recognizing that among the areas particularly appropriate for government action and cooperation are advanced robot systems that avoid the need for people to work in harsh, difficult or dangerous conditions or environments, this forum is promoting activities that will support such development. The forum results from a working group established following agreement at the 1982 Versailles Economic Summit meeting and whose plan was accepted as one of a number of proposals for international cooperation in the development and application of science and technology at the Williamsburg, USA Summit meeting under the heading or theme "Technology, Growth and Employment".

Countries participating in the forum are Japan and France as co-leaders, plus Germany, Italy, USA, United Kingdom, Canada and Austria with the Commission of European Communities, Norway and the Netherlands attending as observers.

The development of advanced robot systems designed to work in the conditions and environments proposed will require new technologies which are far more advanced than those embodied in the industrial robots of today. Accordingly, and as plans for cooperation develop, it is expected that the Canadian involvement will be primarily by researchers with an interest in collaborating with their counterparts in other countries.

The forum has identified advanced robotics applications in space, ocean, nuclear, mining, agriculture, civil engineering, plant maintenance, fire fighting and rescue operations and services for planning and consideration.

Based on their own integrated research efforts, countries are preparing to conduct the following cooperative activities:

- Exchange of data/information, researchers/study missions (including workshops and joint site studies at appropriate centres) on the R&D activities for advanced robot systems.

- Suggestions for common standards (robot components, interfaces, communication and languages).

- Establishment of common criteria for evaluation.

- Joint evaluation of technical aspects and joint experiments.

To date, the JCF has met four times and workshops have been held on the following topics:

- Workshop on Fire Fighting and Rescue Robots in Japan, August 1984.

- Advanced Robotics Workshop on System Architecture, Intelligence and Man-Machine Aspects in Italy, September 1984.

- Workshop on Advanced Robotics in Mining in France, May 1985.

It is planned to address other application areas in future workshops.

To encourage and facilitate international collaboration, NRC has prepared a "Guide to Robotics R&D in Canada" which will be available for distribution as an NRC report about September 1985. The report is the result of a study commissioned by NRC and undertaken by robotics researchers and specialists at the University of Toronto and the Ontario Robotics Centre. By describing robotics research and development at university, industry and government centres across Canada, and encouraging other countries to do likewise, it is expected that the report will encourage collaboration and cooperation to the maximum possible extent, both within Canada and internationally.

Further information on the broad plan for international cooperation in a wide range of technologies is contained in a report "Technology, Growth, Employment" dated January 1983 by the Working Group on Technology, Growth and Employment established by the Heads of State and Government at the Versailles Summit, June 4-6, 1982, and printed by La Documentation Française in Paris, France.

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