ON FUTURE COAL MINING AND HUMAN UNDERGROUND ACTIVITY

Lubomir Petras

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

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ON FUTURE COAL MINING AND HUMAN UNDERGROUND ACTIVITY

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BACKGROUND

The IIASA Research Program for 1980 includes two Industry Studies under the general heading "Issues for the Eighties". The first of these industry studies is in Coal, in particular hard coal mining underground. The activity in this study to date includes:

-- A task force meeting, to initiate the study held in March 1979 at which eight coal producing NMO countries were represented;

-- A seminar held in Szczyrk, Poland in November 1979 at which technical papers on the following topics were discussed:

   (a) planning for planning (including new mining technologies),
   (b) management and organization,
   (c) environmental problems.

   This seminar was attended by representatives from the USSR, UK, Poland, FRG, Czechoslovakia, Italy, Hungary, USA, and Austria.

-- A planning meeting was held at IIASA in April 1980 which was attended by representatives from the UK, Poland, FRG, Czechoslovakia, and the USSR. At this meeting it was agreed to arrange a task force meeting on "Planning for Planning" in the coal industry in November/December 1980 at IIASA (see Appendix A for draft agenda), and that this would include a discussion, proposed by the present author, of new mining technologies, e.g., robot mining devices, to be considered in the context of anticipated shortage of underground manpower.

This Professional Paper provides background material for that discussion.

HUMAN ACTIVITY UNDERGROUND (GENERALLY)

> Coal mining is by far the most dangerous major occupation in the US today. Over 100,000 miners have been killed in the mines since 1900. (Thompson 1979)

Underground work in the future is going to remain unattractive if the present hazards and occupational diseases are not minimized beyond the incremental improvement processes currently experienced--fundamental change is needed. The general public do not have even half a true picture of what underground work is really like. It is only on those sad occasions of great mining accidents that they are shocked by the high numbers of casualties.

Much less, in fact virtually nothing, is known of the hundreds of miners who, due to an every day accident, are compelled to draw a life-long invalidity pension. This shadowy part of underground mining is not publicized and the statistics are seldom clear. No industrial sector claims so many victims every day as the coal industry, particularly hard coal mining. Any air transport accident results in an immediate and thorough investigation into the causes, followed by an attempt to avoid any similar disaster in the future, i.e., the body of the plane is changed, remodeled, together with each part, navigation equipment, etc. And all this is done under the watchful eye of the public. The steady whittling away of human life and health underground gets no such publicity. Nor is cause related to effect. How many of the users of energy produced from coal are aware of the toll they exact when they turn on a lamp? How much does the general public know of the numbers of miners who have to stop working underground due to silicosis, have to change their job and in spite of that change end their lives prematurely? On keeping problems of dust on one side, the generally high morbidity of coal miners and conditions are getting worse. The increasing mining depth brings about higher temperatures (3^{o} by each 100m), higher pressures and other problems. Alleviation can only come through an all-round and thoroughly thought-through innovation process.

Energy forecasts indicate that within two decades coal output will have to increase manifold. But that increase will not come unless human ingenuity and technical know-how are applied underground as much as they are to activities on the surface. It is neither technically possible, nor humanly acceptable. Underground man is no less worthy of concern than the cormorant. This means, amongst other things, that man's work underground should be considered as a consistent whole, an inter-related closed system.

We must draw on knowledge obtained in other spheres, on the surface or in the air, so far as we can but nevertheless we need a complete systems study of underground so that we can see how best to create an underground production system in which man can survive without self-denigration, and so that we can develop the necessary equipment for this high task.

Clearly it is necessary to explore all likely variants of the future development of those areas of human activities which are most likely to have thier impacts on mining, e.g., the construction of future extraction devices. This must not be a haphazard exploration. On the contrary, the close cooperation of mining experts with those from other selected sectors, including pure science, will be required, and that at the international level. A national technological assessment, carried out at this level, could provide the information necessary for decision, and would be of value to:

- -- experts from the mining industry and selected cooperating industrial branches, including specialists for working out prognoses in the areas concerned;
- -- systems analysts of the mining industry, ecologists, demographers (migrations), concerned with economic and social planning;
- -- experts concerned with energy and power scenarios who would thus influence the future demand for coal (especially coal for synfuel) in relation to new technologies.

Modernization in the coal industry has, in all its history, been lagging behind (see the delay in the usage of air and electrical motors, transport equipment, etc.). This situation can only be changed if the underground activity is considered as a relatively independent system (as far as research is concerned), and an "open system" (when we think of the cooperation with experts from other branches).

BACKGROUND TO THE PROBLEM

> ...technological development in the coal industry and the supply of skilled labor are unpredictable and make major investment and planning decisions in the EIGHTIES more difficult and complex than ever before...
> (IIASA Research Plan 1980-84)

For long-term planning of the development of many national economies, it is necessary to understand the future potential of their coal industries, especially that of deep mined hard coal which is an essential element for steel production. It is, therefore, necessary to take account of the fact that in 10-20 years technological progress in the mines will have to compensate for an anticipated lack of manpower. This is not a simple task for mining research, as pointed out, e.g., by the Chairman of the NCB (UK), who said:

> We know what we are aiming for at the moment in terms of our mining resource effort, but mining will undoubtedly change. How will it change towards the end of the

century or beyond? What new techniques or devices will be employed?, etc. If we can guess at them now, then we should be instituting immediately the research that will bring them to fruition in due course.

By implication this is a major element in IIASA's project 'Coal--Issues for the Eighties', for decisions about that research are precisely one of the major issues for the industry in the eighties. What is known about this in the different national industries? What information is necessary for a decision?

The answers to such questions are not simple, and has been given different forms according to the author's particular sphere of interest. There must inevitably be many approaches. If, for example, we want to know something more about the possibilities of improving present conventional mining methods by using new types of explosives in the future, we would view this quite differently than a similar object of mining research, such as measuring the characteristic features of surrounding rocks. Such perceptions of the need for mining research is quite different from that of the planner who is concerned with integrated systems, or health specialists concerned with safety and morbidity.

Some see the question as concerned with improving existing methods such as a "long-wall face" by better automated supports. Others are interested in more revolutionary achievements such as a remote control mining robot system. So far as Czechoslovakia's coal mining research of these future possibilities for human activities underground is concerned, there isvery intensive and permanent research interest in future "manless" mining (this means not quite without miners). It is clearly realised that if we want to utilize the advantage of the future mining method by the year 2000, we must implement R&D strategies in the EIGHTIES!

Let us try to take the matter further by identifying some of the requirements for an 'ideal' mining system (Petras, 1980-1).

(a) To minimize the number of workers whose activities are underground;

(b) To minimize the number of drifts, corridors, and shafts (this means avoiding production of stone);

(c) To improve the recovery factor;

(d) To simplify the ventilation systems (through bore holes from the surface or from main drafts just above the explored seam) so as to save costs and improve working conditions;

(e) To transport underground coal without the breakdowns that arise in conventional equipment;

(f) To reduce operational cost (especially for supports) and investment cost (especially for underground roadways, corridors, etc.);

(g) To develop means of exploiting 'difficult' seams, e.g., seams with rock pumps, pressure pumps, etc.;

(h) To simplify the development of mines; and

(i) To increase the safety of miners.

No single mining method with the above nine characteristics exists. It was, therefore, necessary to develop a survey of current and future technological possibilities in underground mining of coal from different R&D programs. Some important methods in this area are briefly described in the following section.

FUTURE TECHNOLOGICAL POSSIBILITIES

1. Mechanical Cutting: At the present time the bulk of hard coal extraction in NMO countries, and indeed in the world as a whole, is done by mechanical means, whereby a tool such as a cutting pick or plough blade is used to break lumps of coal from the solid face.

2. Use of Explosives:

-- Conventional techniques,
-- Peaceful nuclear explosion.

3. Cutting by Pressurized Water:

-- Hydraulic mining of coal (in most cases the water pressure has been less than 35 MPa),

-- For cutting rock much higher pressures have been used, up to 1500 MPa (the process is at present inefficient, the consumption of energy per unit mass of material removed being about ten times that for mechanical cutting).

4. Remotely Controlled 'Moles': Robot devices that carry out quasi-manual explorations when instructed by

(a) not too remote human operator (e.g., under a long-wall face),

(b) remote human operator, from a manned underground control base, of the machine's situation is brought to him via monitoring systems, sensing systems, electromagnetic systems, etc., (better sensors incorporating microprocessors and improved data transmission and a small computer would steadily improve the protection), and

(c) human operator from surface with utilization of computers and other special equipment.

5. Underground Gasification: Research work is being carried out internationally. Field trials are going on, or being prepared in the USSR, USA, Belgium, FRG, and Czechoslovakia with the latter two specifically intending to investigate the problem of gasification in depth. Other methods pertaining to this group are, e.g., pyrolysis, complete and quenched combustion (coal or oil is fed with air and ignited, after which water is pumped in to pursue the flame front and generate steam).

6. Solvent Digestion: The method is based on the digestion of coal in coal-derived oil, e.g., authracene oil. In recent years interest has been shown in the application of this technique to in situ processing (in the USA and the UK).

7. Chemical Combination: A US patent exists on a process involving the use of materials such as ammonia and aqueous motuguol which act as surface active agents and reduces interlayer forces at the natural interfaces present in coal and thereby cause the coal to fragment. The nature of the fragmentation apparently also assists in the subsequent separation of sulphur and other inorganic materials.

8. Microbiological Degradation: Method which has been developed especially in the USA (University of North Dakota), in the UK (Microbiological Research Establishment of Portou) and the USSR. Coal, being an organic chemical, can conceivably provide a life support medium for a micro-organism. It is possible that in digesting coal some micro-organisms might produce a significant yield of low molecular weight degradation products. No micro-organism has yet been identified but apparently no detailed search has been made.

Points 5-8 are, however, unlikely to be for hard coal. We therefore need to concentrate on methods 1-4. In the author's opinion method 4 offers real potential for research development perspective. The main part and condition for method utilization (especially 4(b) or 4(c)) is the robot device (electronic mining equipment). In some countries a great deal of attention is being given to the limited form of robotry (e.g., USSR, UK--"telechir mining", or Czechoslovakia--"EFIDES mining modul").

However, today's reality, so far as the R&D robot mining device is concerned, is relatively the same as it was 5-10 years ago. The main reason for this is that the major effort of R&D has been the development of automation in hydraulic supports and mining combined. In Czechoslovakia this has been because of the following assumptions:

-- long-wall face is the best mining method;

-- it is necessary to improve the present level of automation of this method;

-- it is not possible to mine without a support in a long-wall face; and

-- the present way of ventilation is suitable.

These opinions have changed and the effort has been concentrated especially in:

1. R&D of different mining methods than long-wall face ones;

2. R&D of geological exploration methods which are necessary for the work of robot devices in a coal seam (removing geological uncertainty); and

3. Clarifying the main features, functions, etc., of the robot electronic device ("EFIDES") and problems of its testing in present long-wall faces.

In response to the first item, since 1978 mining research in Czechoslovakia has been developing an entirely new mining method, which has been called "Underground Exploration of Coal Seams by the Method of Concave Centrifugation Continuous Caving Mining" with the robot device "EFIDES" and with hydraulic transport and exhaustion of mixed air and CH_4, CO_2, CO, H_2, etc. It is already clear from the name of the method (in short "PEEM") that it is quite different from present methods (see Czech. invention No. PV535280).

In response to the second item, a solution of geological uncertainty was considered to be the most important condition for future successful mining by robot device. Thus, a survey of the seismic method has been developing since 1970. This method has been called "transverse seam wave" (see Czech. patent; in the US the patent has the number 3,858,167).

So far as the third item (robot device) is concerned, it is a main part and condition for method utilization, as previously mentioned, and this problem of development of the robot device (mainly its reliability) cannot be solved only by the coal industry, as other problems--e.g., seismic survey outlook, new ventilation methods, etc. And as it is the central core ofmany future main problems of underground mining, it is necessary to find how the problem can be solved and in what stages.

WHERE IS THE MAIN BARRIER?

The potential value of the robot device for the coal industry has been known since the last century. This is quite natural, as the process of utilizing some mechanical or later electronic moles directed and controlled from the surface by coal mining has been a very seductive one. However, some authors of this "method" ignore the many scientific, organizational and engineering problems that exist (e.g., they do not account for such essential matters as transport of coal, ventilation, maintenance of devices, etc.).

The robot device problem appears as the "tip of the iceberg", whose main body is much more general than other branches of industry and economic sectors. This is a logical concept, as the robot device will be produced and composed of different parts and equipment from the following:

1. Electronic industry: microprocessors, monitoring systems, sensing systems, electromagnetic systems, small computers, etc.

2. Chemical industry: new hard materials for cables, cathing, diving suits, etc.

3. Light industry: automation equipment, remote control, closed-circuit television, phones, transmitters, etc.

4. Transport sector: hydraulic transport, ducts, pumps, etc.

5. Machinery sector: equipment for ventilation or exhaustion and cooling equipment, etc.

6. Heavy industry: equipment for measuring temperature into dust, environmental and other experiences with operation in rigorous conditions.

7. Nuclear sector: parts for manipulation under different circumstances and which require particular reliability.

8. And others: (military sector, health sector, cybernetic resources, cosmic sector, research institutes of these sectors, etc.).

However, until a clear specification is prepared it is not possible to effectively draw in the industries with the necessary skills.

In spite of the fact that the coal industry has been working for a long time on various predictions, short and long-term forecasts, scenarios, prognosis, etc., there has been very little conceptualizations (Häfele 1979). In other words, the requirement for such new mining methods and robot devices need to be worked out on different levels of management in the coal industry, and from different points of view. For example:

1. Technical (ventilation, transporting coal, maintenance, etc.),

2. Safety (manned underground control bases),

3. Management (monitoring, computer-systems, etc.),

4. Organization (development of mines, utilization of results from development of robot devices step by step, etc.),

5. and others.

In order to overcome this, we need:

-- dissemination of needs of the coal industry (not only yesterday's) into public and other sectors and industry branches;

-- present level of procedures for evaluating technology development options (R&D strategies for mining research);

-- timing for working out of individual stages of this development of the robot device (it is important for the solution of present-day and even yesterday's problems as well).

This does not mean that existing research should be in any way discontinued. Rather it is necessary to create a new community to discuss these problems.

POSSIBLE ROLE OF IIASA

As stated in the introduction of this paper, these problems in the coal industry relate not only to IIASA's Industry Studies "Issues for the Eighties" but also to work in other Areas and Programs in IIASA.

-- Energy Program (ENP)--Task 3--mining coal by new methods for conversion processes based on nuclear or solar heat-coalplex, or for synfuel production (Petras, 1980/2),

-- Resources and Environment (REN) Area--Task 2 (environmental quality control and management), Task 3 (resource assessment and accounting--WELMM),

-- Human Settlements and Services (HSS) Area--Task 3, Manpower Analysis (health of miners, hazards, etc.).

Within the framework of MMT's point of view a study of new mining robot devices for future mining methods would be relevant to:

-- Task 1 (problems of technological change--innovation), because the task exploring the direction of changes and identifying the impacts, stimulants, and barriers of this technological change for the new robot device is very significant (especially, if necessary, to start with working out systems analysis of future possibilities of those new mining methods);

-- Task 2 (organizational management), appreciation of today's application of small computers for modeling different relationships between today's and future mining technologies--this means to start work on a simulation software tool which would form part of a decision support system for coal mining industry managers;

-- Task 3 (management of interorganizational problems), questions connected with reliability (risk) of the robot device (e.g., EFIDES) in underground operations.

Simultaneously, the problem of judging future mining methods for coal industries has other suitable features in IIASA research:

-- it is in a long-term task, whose intensity of solution can be variable;

-- it can be disseminated into several partial tasks with different timing;

-- it requires experience, knowledge over achievements from different industries and research sectors (see above), and for this reason IIASA is very suitable;

-- there can by very intensive internal collaboration (today 7 tasks) and external ones also.

It is important to undertake such a study from a comprehensive systems point of view, so as to compare the costs of alternative mining methods in the light of their systems effect. (One method is given in Petras 1980/2).

CONCLUSIONS

Coal remains the main source for the coke needed to produce steel and its associated products such as cars and bicycles. It is therefore vital to examine the potential and the implications of new mining methods, particularly in view of the need to reduce the number of men employed underground. Two major factors are improving the certainty of geological predictions and also of equipment reliability. In Czechoslovakia it is thought that these two factors will best be achieved by seismic techniques, in the first place, and by the use of a robot device on the other. However, if the necessary break-through so far as a robot device could be obtained, many new possibilities would be created--the robot mining device would only be the tip of the iceberg.

The fact is that too often developments have only been considered on an incremental basis, and that an overall strategy or conceptualization is generally missing. In view of the present state of knowledge, some exchange of ideas amongst peer groups from many countries seem desirable.

IIASA would be a natural focus for this work. It would be in full harmony with the third of IIASA's objectives, namely, 'To achieve application to problems of international importance'. The problem is of a long character, suitable for collaborative work.

As a start some careful costing of current methods is desirable for making comparisons. This could be compared with estimated costs of robot device (mole) mining. A start could also be made at the forthcoming task force meeting on 'Planning for Planning' in the following discussions:

-- forecasting productivity and the effects of the new mining technology (PEEM),

-- assessing manpower requirements, availability and training.

Beyond this, it would be necessary to undertake detailed systems studies and to integrate the work with other IIASA tasks.

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APPENDIX

IIASA INDUSTRY STUDIES: COAL

DRAFT AGENDA

PLANNING FOR PLANNING TASK FORCE

	a.m.	p.m.
1 Mon.		Introduction / Reserves Assessment -- Quantity -- Quality -- Geology [REN task 3]
2 Tue.	Mining Method Evaluation/Layout Assessment [REN task 3]	Systems Analysis Approach for Assessing Manpower Requirements/Availability and Training [HSS task 3]
3 Wed.	Systems Approach for Forecasting Productivity and Effects of New Technology [MMT task 2]	The Effect of Risk or Appraisal [MMT task 1&3]
4 Thurs.	Site Selection including Environmental Impacts [REN task 2]	*These two sessions devoted to identifying interrelationships and to general discussion
Fri.	* / Closing Remarks	

[ ] - possibly cooperating with other IIASA tasks.