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A BILL TO ESTABLISH A NATIONAL MINING AND MINERALS POLICY

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E.P. Pfleider Statement pp.103 -107

(The statement referred to follows:)

STATEMENT OF EUGENE P. PLEIDER, PROFESSOR OF MINERAL ENGINEERING, UNIVERSITY OF MINNESOTA, AND CHAIRMAM, RAPID EXCAVATION COMMITTEE NAS/NAE OF NRC

U.S. MINERAL POLICY SHOULD SPONSOR UNDERGROUND RESEARCH AND DEVELOPMENT

The problem

Mr. Chairman and members of the Senate committee, the mining industry of the World and particularly of the United States, has made a complete reversal from underground to surface mining methods since the turn of the late 20th century. This has occurred even as average ore grades are decreasing and strip ratios rising.

In the early 1900s there were over 100 underground mines producing from the three iron ranges of Minnesota -today there are none. Practically all of our coal prior to 1930 was mined underground; today over 1/3 is from surface operations and that percentage is increasing. Although world mining has not changed the surface techniques as rapidly as has EU S industry the shift is escalating will approach our figures shortly. A comparison of World and US production figures are shown in table 1, taken from the AIME Surface Mining volume, and the trend rates for the US are depicted in Fig. 1

TABLE 1. Estimated World and U.S. Production of Crude Ores by Surface Mining, 1964 (Table 1.1-1 From AIME Surface Mining Volume)

	World			United States			Total U.S. percent of world
	Millions of tons			Millions of tons			
	Total	Surface	Percent	Total	Surface	Percent	
Metallic ores	1,800	900	50	458	376	82	25
Nonmetallic ores	1,000	850	85	148	114	77	15
Clay, stone, sand and gravel	3,000	3,000	100	1,657	1,621	98	55
Coal	3,000	1,000	33	504	176	35	17
Total	8,800	5,750	65	2,767	2,287	83	31

There are various authorities including Allsman[1] and Howard,[2] who feel that future conditions will force a reversal of this trend - with a gradual shift back to underground. One important reason is the exponentially rising standards for minerals as shown in tables 3 and 4 of the NAS report on Rapid Excavation, Publication 1690,1968. Furthermore, changing public attitudes on environmental control will, to some extent, tend to increase the cost of surface operations. Perhaps the greatest effect will come from improved geological and geophysical techniques that will uncover mineral deposits beyond the economic depth of surface stripping. Furthermore, as present pits reach their stripping limits a changeover to underground should result. A comparison of the potential zones available to underground versus surface mining methods is presented in Fig. 2. An interesting potential in this respect is the underground mining of Minnesota taconites.

But such shifts will be slow incoming if we fail to escalate our productivities in underground excavation methods considerably more rapid than that in the past. Surface mining today has productivity rates of 100 tons- per- manshift (tms) for small ferrous and nonferrous mines up to 500 tms for large coal and industrial mineral operations, when including all waste or ore handled. By comparison, underground mining achieved rates of but 10 to 60 tms; or about one -tenth of those for surface methods. It is small wonder that strip ratios of 5 to 1 are possible in metal ore mining and up to 60:1 for coal operations.

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TABLE 2. Average Excavation Cost per Cubic Yard of Material Excavated (Crude Ore and Waste)

Mineral	Surface Mining	Underground Mining
Metals	$0.88	$4.34
Nonmetals	1.94	6.78
Coal	.15	4.00

Source: Taken from table C.4 of Operations Research, Inc., report for the U.S. Bureau of Mines.

The impact of these productivity differences are clearly shown in table 2, taken from a report[3] prepared in 1967 for the Bureau of Mines. This same phenomenon has been occurring in the construction industry. In the early part of the century, New York was building its subway system. Tunnels for railroads and highways were relatively common, because it cost too much to excavate large quantities of surface rock by hand held drills and hand shovels or horsedrawn scrapers. Today, massive equipment excavates and transports millions of yards of rock or earth quickly and cheaply. Until recently there was plenty of open space for such activity, and few people worried about the aesthetics.

Planners have tended to consider solutions to pressing problems only in the terms of current technological capabilities. These can and must change. Sweden, given the need and favorable rock conditions, has done an outstanding job in adopting underground excavation for mining purposes as well as total defense and peaceful uses [5]. Its mining engineers, aided by the government, have developed futuristic concepts of underground excavation that match our space program. Fourteen large control centers and shelters have been constructed at vital points. Most of these centers are used also for garages, warehousing, educational and recreational centers, and even industrial manufacturing. For several decades many of Sweden's large hydro-electric stations have been constructed in rock. The development of an underground technology has permitted these construction feats at reasonable costs. To some extent, The US is doing the same with the NORAD project in Colorado

Other countries are turning to the use of tunnels and subways increasing by more. Hamburg, Munich, Montreal, Toronto, and Paris are constructing or extending their subway systems. Japan is driving a 20 km tunnel between the islands of Honshu and Hokkaido. England and France are planning a 30 mile bore under the English Channel. The Mont Blanc tunnel through the Alps by the French and Italians is an epic in tunnel driving using conventional drill-and-blast methods. Such developments will have spin-off benefits to underground mining, if our industry is properly encouraged.

All of these efforts are extending our knowledge and reducing the fear of planners to consider underground excavation. Furthermore, the advent of the continuous boring machine for tunnels, shafts and raises is to some extent revolutionizing our concepts. This unit, together with that of rubber-tired drilling, loading and hauling equipment underground, have been responsible for increasing productivity some 50 to 100% in the past 15 years

However, this rate of improvement is still inadequate to stem the constant encroachment of surface excavation methods, since the latter is experiencing even greater gains. As expressed in the report of the Rapid Excavation Committee at the National Academy of Engineering.[4] For a long time surface excavation*** have received even larger consideration by corporate and governmental planners concerned with urban and resource development.*** The net result is that demands for underground excavation from the construction and resource sector are residual, i.e. projects are planning as subsurface only when there is practically no alternative.

The Background of the Problem.

Why is it that the technology of underground excavation has lagged behind that of the surface?

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First, geological conditions are a principal design consideration in underground excavation. Because of the great variations in rock types, structure and strengths - most of which cannot be predicted in advance of the headings, it is difficult both for the designer and the contractor to achieve the most economic solution. Furthermore, it is generally impossible to select a one-purpose excavator

Secondly, space is confined - requiring a high concentration of rock disintegration energy at the working face as well as the complete coordination of the disintegration, removal and support systems. All of this must be done while providing for the comfort, health and safety of the workmen. The result of these factors is that the current process is expensive and has a rather slow rate of sustained advance.

In addition to these factors, the Rapid Excavation Committee [4] found that the following interrelated technical and commercial features retarded technological change:

(1) inadequate technical knowledge on which to base designed for both the opening and the excavator, and
(2) inadequate industrial incentive to develop better equipment.

We must have better means of predicting rock conditions source to select the best routes or the preferable method of attack. Better information on rock mechanics will permit a more rational design, oftentimes at substantial savings in cost

The markets for surface excavation equipment are large and expanding; sufficient to entice any manufacturer to innovate and market new designs. In fact, many of the new concepts being used underground are modification of units originate ihd for surface applications for example the highly mobile front-end loaders on rubber tires wheels. By contrast the more specialized units for underground use do not command nearly as broader market pants it is a gamble for both the manufacturer and the consumer to try radical designs even if they are favored with a substantial R and D budget.

This limited demand of the past, coupled with the great variability of underground projects both in mining and construction, has been an impediment to industrial incentive. Seldom does the "heavy construction industry" have a sustained interest in the whole excavation process - planning, design, construction and the manufacture and supply of equipment. Further there are few if any standard tunnel diameters around which a boring unit can be built, and patents on new innovations seldom have validity. Thus, the cost of innovations must generally be borne by a single project, and if it fails the contractor must bear the entire cost plus paying a penalty for lost time. As a consequence, there is a natural tendency to go conventional

Although underground mining operations have more flexibility in design and greater incentive to innovate, here again the cost to a single producer or to a manufacturer meeting a singular condition is oftentimes too high

A further deterrent stems from the difficulty in finding design engineers and planners who are familiar with underground operations; as well as workmen who are willing to tackle the working conditions. These factors can, of course, be overcome by the training of personnel and the exchange of physical effort by easily controlled equipment operating in a pleasant environment

Despite these obstacles, private enterprise has made some real gains in underground productivity - largely directed towards the ingenious incremental changes in equipment or techniques. But these improvement rates are inadequate to make underground methods a realistic alternative or to hold rising costs in check. "A radical change in the scope of thinking about underground excavation is needed to achieve that desirable goal."

Impact of environmental control

Much is being written today on the future impact of environmental control - of the air and the land. In our mineral industry, reclamation is becoming a by-word. There is a definite and important relationship between the development of better and cheaper underground excavation and an aesthetically pleasant surface.

The report [4] of the Rapid Excavation Committee describes this relationship succinctly in the following words: "As the nation's gross national product (GNP) increases and discretionary expenditures become a larger portion of total expenditures, national concern for the quality of the environment increases at a faster rate than the rates of growth of the economic expenditures that generate the concern."

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"This urbanization trend poses problems of great complexity to the nation. Certainly, one problem is related to the construction of the physical plant required by the urban complexes - how to create transportation and utility systems efficiently and economically - but at the same time neither unduly disrupt living patterns nor necessarily defile the natural environment. Certainly, another problem is related to the mining of minerals required by the industrial sector *** how to tap resources efficiently and economically without disfiguring the countryside.

" ***current concern about environment is providing an appreciable increase in the number of these residual public needs EG parking spaces and water and vehicular tunnels. Moreover, new needs are being defined that seemingly can be satisfied only by placing greater demands on underground excavation technology.

***In most of these proposals, all costs are passed on to state or federal taxpayers, and these costs are on the rise."

One of the currently suggested solutions to this problem is the application of increasingly stricter environmental controls, and this is being done. Another and better answer is to so improve our underground excavation techniques that the planners have an alternative choice. Such is the course followed in the proposed Sloop project for the Safford copper deposit, featuring the use of atomic energy and *in-situ* leaching; and in the oil shale projects where either large-scale room-and-pillar mining methods or *in situ* burning are being considered.

Potential for Underground Excavation.

Various estimates have been made as to the potential for underground excavation within the next decade or two. A recent study [3] for the Bureau of Mines, based in part on a survey of federal agencies, indicates that during the eight-year period of 1968 -1975, underground activity will comprise about 1000 miles of tunnels (subways: 85 miles; urban highways: 123 miles; intercity highways: 210 miles; water supply:528 miles) and over 5 billion tons of crude ore (metals: 874 million; nonmetals: 899 million; coal:3,346 million).

The NRC/NAE Committee on Rapid Excavation, assuming conservatively that underground excavations will *(a)* maintain its relative share (22%) of the construction- oriented- market); *(b)* maintain its relative share of the coal-mining market; and *(c)* lose its relative share of the remainder of the mining-oriented market to the extent that its current value will remain constant; estimated the demands as present as presented in Table 3.

TABLE 3. Estimated Cumulative U.S. Underground Excavation Demands for the Decades 1970-79 and 1980-89
(In billions of constant 1964 dollars)

	1970-79	1980-89
Construction-oriented demand	13	22
Mining-oriented demand[1]	16	18
Total demand	29	40

[1] Includes coal-oriented demands amounting to $12,000,000,000 and $14,000,000,000 in the decades 1970-79 and 1980-89, respectively.
Note: This is table 6 in report of Rapid Excavation Committee, p. 42.

These quoted estimates can be considered conservative, in the sense that they include only the conventional uses of underground excavation. They do not, for example, include such potentials as underground storage of oil and gas, warehousing, or for recreational educational centers or industrial plants as used in Sweden and now envisioned for the model cities being proposed.

The Solution and the Benefits

What then is the solution to our problem? - A massive and sustained development and research effort is required to reverse the almost total domination of mining and of public construction by surface excavation methods.

The planners, designers and engineers of the future must be educated to the advantages of this 4th dimension – i.e., below the surface - much as the pioneers of aviation and now Von Braun and his group have conquered outer space. Their accomplishments were made largely through the expenditures of tens of billions

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of dollars of government monies; but the spinoff effects have been tremendous. We need that same zeal of conquering new horizon below the surface, realizing that there are many side benefits, such as

(a) Direct cost reductions - resulting in savings both from normal UG applications and from those surface projects converted to UG because of the cost reductions;
(b) Preserved surface land values;
(c) Reduced surface activity disruption costs;
(d) Aesthetic benefits to surface environment; and
(e) Improvement in our balance of payments position - the U.S. is becoming increasingly more dependent on imports of their mineral demands; iron ore (40%), copper metal (22%) lead and zinc (27%). The U.S. trade deficit for mineral products was approx.$3.2 billion for1966., and of this $1.5 billion was for metal and nonmetal ores and $1.7 billion for energy fuels.

Furthermore, a stemming of this tide toward mineral imports can provide tens of thousands of jobs for our citizens.

The Rapid Excavation Committee [4], in addressing itself to these points, made the following recommendations.

1 Over and above current government and industry research and development efforts, a 10-year, $200 million, *[Equivalent to $1.5 billion in 2022]* federally funded research program should be immediately undertaken and vigorously pursued to establish the technological basis for reducing the costs and improving the sustained rate of advance of underground excavation.

2.Individual research projects should be selected for inclusion in the program on the basis of their potential contribution –

(a) to the coordination of the several elements of the underground excavation process into a highly engineered system
(b) to the improvement of the basic knowledge required to subsequently effect engineering advances in the several cited areas of -
  (1) geological conditions
  (2) rock mechanics
  (3) rock disintegration
  (4) materials handling
  (5) ground control
  (6) environmental control and safety.

3.As an essential element of this supplemental research effort, a federally funded field laboratory should be established and equipped to test full-scale integrated excavating systems on a range of geological conditions
4.Within the government, an interagency committee should be immediately established-

(a) to recommend how federal sources may be used efficiently to initiate and maintain the research program.

(b) to coordinate the overall research program; and

(c) to interpret research results and disseminate pertinent information to all parties with interests in rapid excavation.

5. A government/industry/academic advisory committee should be established concurrently to assist the interagency governmental committee and to vigorously encourage and assist industry to use the research results in the development and application of improved excavation equipment and processes

By following such recommendations, the committee feels that the knowledge gained will set the stage for reducing overall underground excavation costs by at least 30% and increase the sustained rates of advance some 200 to 300 percent by 1990.

If this objective can be achieved, the net saving on the $35 billion of construction-oriented underground construction(estimated as a minimum for the 1970 to 1979 period In Table 3) is $2.5 billion when discounted at the government cost of borrowing at 6% -more than 12 times the cost of the research program looking at it another way, the internal rate of return on the $200 million research investment, if predicated only on the savings from government oriented projects would be about 40% per year.

The economic justification cited above does not include the benefits derived by the US because of its improved ability to produce its mineral requirements at competitive costs; with a resultant improvement in our balance of payments. No do the calculations consider the side benefits of improved environmental conditions or the faster travel speeds in the metropolitan areas.

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The committee further concludes that “If the public sector initiates this added research effort and concurrently evolves a realistic technology transfer plan, the competitive nature of the excavation industry is such that the engineering development needed to convert results into operable equipment and processes will be privately made.”

Shouldn't such benefits merit equal consideration for just a fraction of the funds going into outer space research? And isn't it worth the coordinated efforts of the civil engineer the planner and the mining engineer - working with the mining, construction and equipment manufacturing industries -to bring this about?

Since underground excavation is multi-disciplinary, and a world problem, we must call on talents from all fields, including those from abroad, to assist in the solution. Towards this end, the professions are holding numerous symposia to determine the present “state of the art.” The Tunnel and Shaft Conference held at the University of Minnesota last May, and the Symposium on Research and Development in Rapid Excavation, scheduled at Sacramento State College in October, are but two of such meetings. Additionally, the American Institute of Mining, Metallurgical and Petroleum Engineers, as well as the American Society of Civil Engineers are establishing committees to further this greatly needed development in the art and science of underground excavation.

The Congress of the United States is the only arm of the government that can initiate this program of converting large potential tonnages of underground mineral resources to the economic reserve status. This it can do by sponsoring a long range, coordinated R&D effort on a total underground excavation system as a part of the country's Mineral Policy.

In closing, I wish to thank the Committee for permitting me to make this presentation in support of the Minerals Policy Bill.

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[1] Allsman, Paul T., "Current and Future Status of Surface Mining," Chapter 1.1 in Surface Mining Volume, AIME (1968): 3-16 E.P. Pfleider, Editor.
[2] Howard, Thomas E., "Rapid Excavation" *Scientific American* (November 1967): 10 pages.
[3] Lago, A., Williams, P.D., Nisselson, H., and Kushner, H.D. "Projections of Applications and National Benefits of a New Rapid Excavation Technology," Operations Research, Inc., for the U.S. Bureau of Mines (Sept.8,1967):112p
[4] National Academy of Sciences, "Rapid Excavation - Significance, Needs, Opportunities" (August 1968)
[5] Kastrup, Allan, "Rock Excavations for Total Defense and Peaceful Uses" Bulletin E.15 The Swedish Institute, Stockholm (1962): 17 pages.

Professor Pfleider's Oral presentation is recorded on pp.109-115 of the original text. (See link below)

https://www.google.com/books/edition/Hearings_Reports_and_Prints_of_the_Senat/ciA2AAAAIAAJ?hl=en&gbpv=1&dq=NAE+1964+Committee+on+Rapid+Excavation+Techniques+Pfleider+Chairman&pg=PA103&printsec=frontcover (See pp.102-115)