MMSD

Mining, Minerals and Sustainable Development

February 2002

No. 38

Status of Education of Mining Industry Professionals

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Mining, Minerals and Sustainable Development is a project of the International Institute for Environment and Development (IIED). The project was made possible by the support of the World Business Council for Sustainable Development (WBCSD). IIED is a company limited by guarantee and incorporated in England. Reg. No. 2188452. VAT Reg. No. GB 440 4948 50. Registered Charity No. 800066

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Over the next 50 years the world will use five times the mineral resources that have been mined to the year 2000. To meet this predicted increase in demand, the industry must grow as an internationally competitive sector, underpinned by innovation and technology. To achieve this, the industry requires competent professionals possessing sophisticated knowledge and advanced technical and leadership skills.

(AusIMM)

1 Overview: The Changing Pattern of Mineral Industry Education

The mineral industry needs a steady supply of skilled professionals entering the work force. Are these professionals being trained? The simple answer is a qualified yes. Initially it must be recognized that as mineral development has become more complex and technical, the training of mineral industry professionals has adjusted to reflect this. Today's mining engineer or metallurgist is a very different person from that of even a decade ago, and we can expect at least as great a change in the next decade. How do the engineering schools keep pace, and continue to turn out "competent professionals possessing sophisticated knowledge and advanced technical and leadership skills?" This is a continuously self-adjusting system, sometimes voluntary, sometimes forced, but always changing.

A good example is metallurgy. The host of Departments of Metallurgical Engineering that existed 40 years ago has dwindled to a precious few while the number of Departments of Materials Science and Engineering in which metals form one group of materials along with ceramics, plastics and composites has blossomed. This is change, and this is progress. At many universities mining engineering is now taught as an option in a more general program of civil or resources engineering rather than in a dedicated department. In these programs mineral related subjects are no longer part of the core and are being absorbed into broader fields of engineering education that serve a functional rather than an industry need. This is a normal evolution, dictated by the demand of industry for excellence and by the instinct of institutions to survive. Throughout this report there will be evidence of such evolution and adaptation. Although we may not always agree in specific cases, change is generally good.

The situation varies from country to country, but the trend is clear. In most industrial countries where mining is no longer a dominant industry (England and Japan would be examples), mining engineering as a discrete field of study is in decline. In many cases it has been absorbed back into general engineering or become an option in civil engineering or part of a resources or environmental engineering program. In Japan, where 20 years ago there were mining engineering departments at many of the major universities, mining is now taught in a series of courses in resource engineering or environmental engineering departments. This trend is also apparent in Europe and America, where mining schools, once relatively common, are now a rarity, or exist in name only as with some of the French Ecoles des Mines. Over the past decade the number of mining engineering programs in the UK has fallen from 10 to 3 and in the last five years programs in the US have fallen from 27 to 22 with further reduction on the books.

Is the trend the same in the North and the South? One would have to say no, because the situation is not the same. In developing countries where mining is a major contributor to the economy, mining engineering is still an important field of study in the universities, providing trained engineers for the local and regional mining industry. One respondent noted that with the decline in mining in the North, training programs can be expected to shift to the South, including Australia. Mining programs in developing countries tend to concentrate on undergraduate training, with research-oriented students going abroad for their postgraduate studies. We see this in Latin America, Africa and Asia as well as with the many well-qualified graduate applicants who move to Europe and America from countries like China and India. Australia continues to have a high demand for mining engineers and may be the exception that proves the rule. As will be noted, Australia can serve as a model on a number of levels. As an aside, it is of interest to note that foreign students at the Papua New Guinea Institute of Technology (36 mining students) come mainly from the Solomon Islands.

In this evolving pattern, graduates from developing countries move on to institutions in the developed countries where, as one would expect, there is a relatively high enrolment at the post-graduate level with a relatively high percentage of foreign students. Thus, while many undergraduate programs in Europe and America have downgraded mining engineering as a major, their mining departments (under whatever name) are supplied with as many post-graduate students as their fellowship quotas can accommodate, mainly from other countries. Many of these graduate students stay on in the host country after they have obtained their degrees, and compete in that job market.

Consider how this trend is evidenced at some of the famous American mining schools. At the Henry Krumb School of Mines at Columbia University, the first to be established in America, mining engineering is now taught under the title of Earth and Environmental Engineering with a very limited enrolment. At the Pennsylvania State University, mining engineering is still taught, but in the Department of Energy and Geo-Environmental Engineering. At Michigan Tech the Department of Mining and Materials Processing Engineering is in the process of being dismantled, with mining going to geology and materials processing to chemical engineering.

The Royal School of Mines in London recently (1999) became a part of the T.H. Huxley School of Environment, Earth Science and Engineering, but that move did not save the program. As of August 2001 the Huxley School and its mining program were essentially eliminated due to limited response. Consideration is being given to retaining a Master's Degree program in Mining Engineering as a part of the European Mining Course (see below) but the famous Royal School of Mines may become little more than a name on a building in South Kensington.

At the Ecole des Mines in Paris research on minerals continues to be carried out in a number of special programs, but undergraduate training is limited, and mining is dealt with mainly in a series of high-level, one-year postgraduate programs, many of which include environmental considerations. These programs are coordinated under CESMAT (Centre d'Etudes Supérieures des Matières Premières) at the Ecoles des Mines in Paris, Nancy, Alès and Fontainebleu.

A new program is being developed at the University of Toronto where a grant of C$5 million has been received to help rebuild the mining department. The Lassonde Mineral Engineering program is now in its third year and has four options (1) mineral exploration engineering, (2) mineral processing engineering, (3) mining engineering, and (4) geotechnical engineering. The response to now is not clear.

To this point emphasis has been on training at universities that follow the European – American system. This leaves out the majority of mining students in the world and the situation in the socialist countries is quite different. In Eastern Europe and China whole universities continue to be devoted to the mineral industry, and enrolment is not a great problem. For example, the National Mining University of the Ukraine has separate departments of underground mining, mineral dressing, mine and underground construction, drilling, mine surveying, geology, mine equipment and ecology. Current enrolment is 1825 undergraduates and 83 postgraduates and there are six applicants for each space in the program.

China is the largest coal producer in the world and the China University of Mining and Technology in Jiangsu, Xuzhou, is one of several universities that come under the ministry in charge of coal production. The University has a total of 1700 students and offers BS level degrees in mining engineering (120 entrants each year), safety engineering (60 entrants), communication and transportation (60 entrants), industrial engineering (60 entrants) and fire–fighting engineering (60 entrants). The number of entrants each year is set by the University, applicants exceed available places, and graduates work for the ministry of which the university is a part, so it is something of a closed system.

This is the pattern in China where many of the technical universities are affiliated with ministries such as the Ministry of Geology and Mineral Resources or the Ministry of Coal Mining Industry or the Corporation for Non-Ferrous Metal Production. China even has one university dedicated to gold mining, and another dedicated to mining medicine. It can be assumed that each of these universities has programs designed for the industry it represents, and that coal mining requires a somewhat different approach to drilling or to ventilation or to fire control than does hard rock or industrial minerals mining. Similar differences in approach can be assumed to exist at universities in Europe and the United States, and, for example, courses at the University of Kentucky or West Virginia will reflect the needs of the coal industry while those at the University of Nevada or Arizona give more emphasis to hard rock mining. The recovery of gold or of sand and gravel may be a dredging operation while much aggregate and coal is recovered from open cut mines where emphasis is on earth moving rather than traditional mining. However, this phase of the study has not looked into this aspect of the training of mineral engineers and how the Universities deal with it. This is an area that warrants further attention.

One other variation that affects the number of students enrolled in any subject is the practice at many schools of allocating a specific number of spaces to each field – so many to medicine, so many to industrial engineering, so many to mining engineering, etc. This has implications when the demand for places in a preferred field exceeds the number of places available, but there are still openings in other fields. Drawing on one example, in Indonesia many of the students who enrol in mining engineering may have wanted to study pharmacy or civil engineering. However, since these quotas were full, and many of the general courses in the mining curriculum receive full credit in other fields, students enrol in mining with the intention of switching when a place in their preferred field became available. This system is still used in some Asian and Latin American universities and tends to warp enrolment figures.

Another critical element that has not yet received adequate attention in this review of education is the status of research, both basic and applied, much of which is carried out by university professors and postgraduate students. It is not clear what is happening on this level. As under-graduate enrolment declines the need for postgraduate assistants declines.

At the same time major mining schools, i.e. Colorado School of Mines, Ecole des Mines de Paris, University of British Columbia, etc. are giving increasing emphasis to the research side, and are generating support for research assistants in addition to teaching assistants. This aspect of education warrants further review.

In summary, many but not all of the undergraduate programs in North America and Western Europe are in decline while those in the developing countries and to some extent in Eastern Europe continue to thrive. Graduate enrolment depends in large part on available fellowships, and in general remains constant, with most candidates preferring to study at universities in the North where the research programs are more advanced and are well funded.

2 The Survey

As part of this review, seventy universities world wide that teach mining engineering, mineral processing, mineral exploration and economic geology, were identified and a questionnaire was sent to their fax or e-mail address. The messages were received by 62 of the 70, and replies have been received from about 40. The geographic breakdown of universities that were contacted (with replies in brackets) is: North America 18 (14), Western Europe 12(6), Eastern Europe 7 (4), Africa and the Middle East 8 (3), Latin America 7 (4), Asia 14 (6), and Oceania 4 (3). Annex I consists of reviews of more than 100 representative schools and basic data on about 150 others.

In addition to general information, the questionnaire asked the schools to indicate whether enrolment was going up or down, where their students came from (domestic or foreign,) where they were employed (in mining or in other fields,) how they compare in quality with students of 5 years ago, and with students in other fields of engineering. Respondents were also asked to identify general problems in mining engineering education, and steps that they had taken or knew had been taken at other schools to improve enrolment figures. On some questions there was no consistency in the answers even within a region. Most schools felt that there had been little change in enrolment, that student quality was much the same and that mining students were neither better nor worse than other engineering students.

The question of enrolment may be more complex than simple numbers as is illustrated by a review of the totals for the ABET accredited mining departments in the United States over a ten-year period. Some show reduced numbers, some show small gains, but in most cases there is no significant variation. However, in most cases mining department have fewer than 60 students, and in only three or four do they approach or exceed 100. Here it becomes a question of critical mass. With growing cost per engineering student most mining departments are not large enough to take advantage of economies of scale and are under pressure to reorganize or combine. Compare this with the situation at the Stanislav Stacszic University of Mining and Metallurgy in Poland. The Faculty of Mining alone has six departments (underground mining, open-strip mining etc.) and a total of 1532 full-time and 1051 part-time students along with 139 teaching staff (15 full and 24 associate professors.) Clearly this is above critical mass but by the same measure it can be argued that enrolments of less than 100 are at or below the break-even point.

In many schools the answer has been to combine departments working in related fields, with mining most often linking with civil engineering. As will be noted in the following sections, an alternative might be to integrate horizontally rather than vertically, and to link with the mining departments of other schools as has been done in Europe and is being considered in Canada and Australia. This may require some adjustments in the United States, as under present policies it would be difficult for such programs to be accredited by ABET on the undergraduate level.

Respondent comments are of interest and will be dealt with in greater detail in the next section. One noted that while mining enrolment had remained steady at best, enrolment in fields such as business had increased more than tenfold. Another came up with a possible answer – the need for more double degrees in which mining and commerce or mining and business might be attractive options. There was also the suggestion that other fields might consider mining engineering as an option or as a minor. Several respondents mentioned the potential of web-based courses, eLearning, distance learning, virtual universities, different names for much the same thing. There is interest in collaborative programs in which students or professors rotate among participating schools that serve as Centers of Excellence in a selected field – rock mechanics, ventilation, etc. There was a general cry for greater involvement of industry.

Where do our graduates work? Many schools report that more than half work in fields not related to minerals. The Indian Institute of Technology, Kharagpur, with over 100 mining majors reports a situation that may be more common than is generally recognized. IIT is a high level school that draws its candidates from the best high school graduates in India Most candidates want to study computer sciences or electronics and the best occupy the vacancies in these fields. Mining engineering students come from the lower (still good) levels, and most mining graduates (60%+) end up working as software engineers because of the computer training they have received in the mining program.

Even within the mineral industry most graduates do not work at or near the mine face. Many work in surface mining, dealing with the vast quantities of aggregates (sand, gravel and crushed stone) that are consumed each year by building and construction industries, or in the open-cut coal mines that produce much of our fossil fuels. Mining then becomes a highly structured form of earth moving. With improved technology and the growing use of robotics, mining is becoming less arduous and today's mining engineer often works alternate blocks of time at the mine and at home. And, as in most complex situations, additional pay can be a substitute for perceived discomfort. How else would they staff oil platforms in the offshore areas and research stations in the Antarctic?

What percentage of graduate students is foreign? In many graduate schools more than half are, and, as has been noted, many of these stay on in the host country to compete for available jobs. It should also be noted that graduate enrolment provides the stock from which future professors will be drawn. In fact, one respondent called attention to the fact that a high percentage of new faculty were foreign, and although this adds diversity, it also means that faculty often have limited contacts with local industry and with local customs.

What is the situation of mining professors? As noted, with the preponderance of foreign graduate students, there is an inevitable shift to professors with a foreign background. The situation is exacerbated by a salary structure that makes most teaching posts non-competitive with industry. The best postgraduate students have more attractive options. Partial solutions that many universities already make use of include recruiting industry experts to serve as part-time professors in specialized fields and generating industry endowed professorial posts.

Throughout the responses there was the continuing awareness of and concern about the negative image of the mining industry -- the picture of the mining engineer as someone who works in remote places under difficult conditions -- the general image of the industry that the Global Mining Initiative is dedicated to improving. Lewis Mumford wrote "Apart from the lure of prospecting, no one entered the mine in civilized states until relatively modern times except as a prisoner of war, a criminal, a slave. Mining was not regarded as a humane art: it was a form of punishment; it combined the terrors of the dungeon with the physical exacerbation of the galley." (Technics and Civilization, 1934) Certainly the image has improved since those times, but there is still some way to go.

The comments in response to the questionnaire were very useful, not only in identifying areas that need further attention, but also in identifying possible solutions. The following sections draw heavily on information provided in the survey and on follow up phone discussions with a number of the respondents.

3 Where Do We Go From Here?

This is the basic question being asked by the Global Mining Initiative as it concerns the world mining industry, with emphasis on how to come to terms with the negative image of mining. The various MMSD reports under preparation can be expected to give a good deal of attention to this question that is also the major problem in mining engineering education. How do we improve the image of mining? In the case of mining engineering education this is fundamental, as we must recruit future mining and minerals engineers from the 16 and 17-year-old high school students who are choosing careers.

Since the question of image will be the subject of other reports it will be dealt with only marginally here, but it does permeate the whole exercise. We are looking for answers, and as will be clear in the following notes, there are answers. It will take a sector wide effort such as the Global Mining Initiative to identify and call attention to them, and it will take the follow-up phase of the Initiative to put the answers into a program of action. For the purposes of this report, the strengthening and improvement of mineral engineering education will be dealt with under five main headings:

1. the role of industry;
2. the role of mining associations;
3. the interface with the schools;
4. actions to be taken within universities and between universities, and,
5. learning from experience in other fields.

(Note that there will be significant overlap between these categories)

It will be readily apparent that a great deal is already being done and much information is available for the taking, but the people who need and can use it don't always know that it exists. By the same token, it is very likely that this exercise has only scratched the surface, and as we move forward additional information and initiatives will emerge.

To quote from a recent UNEP report

> Undergraduate minerals education should deliver technical excellence in the fundamental principles of science and engineering, an understanding of broader issues facing the industry, and the ability to continue to learn.

Few would disagree with the three elements identified in this summation.

3.1 The Role of Industry

Industry is the key, and the interest that industry has demonstrated in the case of the Global Mining Initiative as well as in national programs in countries like Australia, Canada and South Africa demonstrates that this is well recognized. With the trend towards globalization and industry consolidation the potential of and for industry cooperation is apparent in all aspects of the problem, including education and research, as will be clear in the following notes.

Industry Advisory Teams: It is critical that industry have a strong voice in the development of any new pattern. An editorial in the Journal of Engineering Education (July, 1998, p 201) notes: "A suggestion that could increase the success of engineering education reform is to form outside advisory teams to work with engineering faculty in implementing changes in curricula and the learning environment. These teams could come from the professional societies or other credible sources and could be made up of members from related industrial concerns who would volunteer a few days each semester to work with faculty members reviewing the content and teaching approaches and advising faculty on expected outcomes, This approach could lead to real-time feedback during the review process." Many schools and departments have such teams. Their role should be better publicized and made more visible and transparent.

Industry Scholarships: These already exist at many universities, and should be increased and given better publicity.

Endowed Faculty Posts: These can take a variety of forms. Most commonly a sum is deposited with the university as an endowment and a faculty post is funded from the returns. Ideally the endowment covers not only salary and allowances but also makes provision for research costs, and perhaps even for a related fellowship. There can be many variations, which would have to be negotiated with the host university

In 2000 Canada allocated C$900 million to a new program of Canada Research Chairs under which 2000 university posts are to be given grants to support research over the next five years. Professors who are recognized as world leaders receive C$200,000 annually for seven years renewable, and professors who show promise of becoming world leaders receive grants of C$100,000 for five years renewable once. Awards are based on university nominations and are within areas identified in the Strategic Research Plan of the university To date one post in mining engineering has been funded along with several in materials science. This could serve as a model for other governments.

Visiting Professors: Much research is currently being done in industry, or at universities with industry support. Because of the speed at which developments take place university staff may not always be on top of the situation even in their own fields. To make education more relevant, many universities draw on industry experts to teach courses as visiting professors. This is a win-win situation in that the university is an obvious beneficiary, and industry has the opportunity to develop close working relations with students and faculty and to become integrated into and provide critical support for the educational system and its basic (collaborative) research component.

Student Internships. Building work experience into the degree program is much more generally accepted and practiced that it was even a few years ago. Although universities in many countries do this, the Canadian experience is perhaps the most intense. In Canada cooperative education has its own national association, the Canadian Association of Cooperative Education that monitors and evaluates the various programs. The University of Waterloo, located in an industrial area between Toronto and Detroit, has more than 10,000 students, and over half of them participate in the cooperative education program that formally integrates a student's academic studies with paid work experience. Students spend alternate four-month periods at the university and with an appropriate employer, where they work at a regular job and are paid. An engineering degree takes 5 years, and during that time the student spends two full years on the job. The coop experience must take at least 30% of the time and can take up to 50%. The Waterloo program has access to more than 2800 employers worldwide. Some programs including engineering are only offered on the coop basis.

There are many variations of this program both in Canada and throughout the world, but in Canada this is considered a normal part of the training. At the University of Western Ontario in London students spend 12-16 weeks in paid employment at the end of their 3rd year. At the University of Toronto they can spend a full year between the 3rd and 4th years. This approach has many advantages to both students and industry. Industry can assign trainees to special projects or relatively short-term assignments, and can evaluate them as possible future employees. The students gain work experience, and are paid at the regular rate for their services. In Australia one part of the MTEC initiative is the Industry Experience for Undergraduates program.

3.2 The Role of Mining Associations

The Mining Associations already serve as a valuable link between the components of the industry, bringing together in their memberships representatives of government, industry, universities, and to an increasing extent the other "communities of interest." It is unfortunate that there is no world body linking national associations as is the case in many other sectors, but that may be part of the follow-up of this exercise. The national mining associations in Australia and Canada are taking lead roles in bringing together their universities, and in the US the SME publishes an annual review of the mining programs in the United States.

Country Reviews: The national mining associations or councils are in a good position to review and advise on the mining engineering situation in any country, and in a number of countries they have done or are doing so. The Mining Council of Australia www.minerals.org.au has been instrumental in setting up the Mineral Tertiary Education Council (MTEC) and the Mineral Processing Education and Research Consortium (MPERC). Much of this action stems from a 1998 study titled "Back from the Brink" in which it was concluded that Australia's universities were not capable of meeting the needs of the minerals industry for suitably qualified professional staff. MTEC, which is funded with A$15 million over 10 years, recommends forging strong partnerships between the minerals industry, the academic community and government. A networking of Australian mining schools is proposed with three Centres of Excellence at the University of New South Wales, The Western Australia School of Mines and the University of Queensland. It is recommended that participating universities develop and share modules of undergraduate teaching materials, and collaborate with MTEC to build a world class learning environment. The Mining Council also has an active program of student internships with mining companies, the Industry Experience of Undergraduates Program.

The Canadian Mining Education Council, a group established in 2000 representing all the mining schools of Canada, is carrying out an ongoing study of the situation in Canada. In a recently published review, they noted that in the 1999-2000 school year there were a total of 512 undergraduates, 68 MS candidates and 68 PhD candidates in the 9 Canadian universities that offer mining engineering degrees. It is recognized that with this level of enrolment, it will be difficult to sustain all nine and a proposal is being developed to network the schools so that they complement rather than compete with one another. This may end up with a structure like the European Mining Course (see below) in which schools are selectively strengthened in special areas, e.g. mineral processing or mine ventilation or rock mechanics, and students rotate among the schools. Networking can take place internally between participating schools and externally with groups from other academic disciplines, and with industry, mining associations and the community. The Council identified a range of problem areas including coordinating employment opportunities, reviewing progress of graduates and retention of faculty, changes in teaching technology and the impact of globalization.

Sponsor Short Courses for Practicing Engineers in Special Areas: Mining Associations often hold short courses in connection with their annual meetings, and this is an area that can be further developed. A 10 day course is something that can usually be managed, and a lot of material can be covered in 10 days, especially when there is no examination to pass, and the object is to improve awareness Courses could be tailored to specific situations where, for example, engineers must be trained to deal with local people and situations requiring special care, or where they themselves are working in a particularly hazardous or challenging environment. KCM and other groups in Australia do this regularly, and give their courses throughout Southeast Asia.

A series of outlines for short courses, complete with handouts, audio-visual materials and reference material can be prepared by Mining Associations as part of the follow up, and made available to mining schools and companies as needed We will find that much material already exist in which case it should be widely publicized and shared.

Note: The material in boxes will serve as the basis for recommendations for follow up.

Sponsor Short Courses for High School Students. One initiative in this area is the Australian Student Mineral Venture Program sponsored by the Australasian Institute of Mining and Metallurgy Education Endowment Fund, and aimed at attracting more of Australia's brightest secondary school students to minerals industry programs at universities. ASMV runs four annual programs for up to forty students each. Programs are organized by universities in cooperation with industry, in four regions, (North East – Brisbane, Central East – Sydney, South East – Tasmania or Melbourne, West – Perth). Each course last for two weeks and is a combination of site visits, lectures and career presentations. Courses normally run about 30 students, with up to half girls. About half of the enrollees indicate that they plan to take university training and follow careers in mineral related fields. www.ausimm.com.au/education/asmv.asp This is a program that night be effectively replicated in other parts of the world.

3.3 The Interface with the Schools

Dealing directly with schools is more complex than most people realize. Schools have curricula that are carefully worked out and agreed upon, and it is much more than simply providing teaching materials to the school. There has to be a place for that material in the curriculum. This being said, there is usually some mention of natural resources in the curriculum, and with some effort and ingenuity a place can be found. A possible model for this is a program at Stanford University that is currently preparing a teaching module for the high schools dealing with natural hazards in the Pacific Rim. <www.crowdingtherim.org> In preparing this a group of teachers from the region has been fully involved from the start and has been able to advise on what will be acceptable and what will be difficult to accept. If material on mining is to be developed for direct use in schools, teachers should be involved in the preparation at all stages. A simpler approach is to work with clubs and social groups in the schools to carry out activities that are related to but not part of the official school program.

Providing Information For Teachers And Students In The Secondary Schools

Much is already being done on this in many countries, and only a few examples can be given. The Mineral Information Institute Inc. www.mii.org is an NGO that began operating in 1980 as a spin off of the SME GEMs program. It is based in Colorado and is supported by local individuals and industry. MII has an active program with more than 35,000 teachers in its database. It provides free materials for teachers including poster packages, and teacher helper packages. As an example, MII has compiled and distributes a periodic table of the elements that lists the elements with information on their history, where they are produced, what they are used for etc. This is a very different periodic table that emphasizes the fact that very many of the elements are minerals. Much of the MII material can be downloaded from their website, and they are now putting their material on CD ROM discs for distribution to schools. (More on CD ROMs below) Today the main users of MII are in the USA and Canada, but MII information is available to any teachers who are interested, and teachers and organizations in other parts of the world might wish to take advantage of this resource.

> As part of the follow-up to MMSD a program should be developed to prepare and distribute material for secondary schools throughout the world, perhaps with some emphasis on schools in or near mining areas. This would involve preparing materials that are not too site-specific and that would have relevance to students with different educational and cultural backgrounds. An existing organization such as the MII could serve as the base for such an operation. For example, MII materials could be checked for relevance and adapted where necessary, then translated into other languages (Spanish initially) and made available for worldwide distribution. Consideration should be given to adapting and producing the materials locally making use of basic material provided by MII and other groups working in related areas.

Promotional Material for Schools on CD's. This is something that could be done centrally, but today's technology allows each university and department to put out a CD displaying and describing its programs and activities. Dealt with in a positive way, mining can be quite attractive, and students and teachers should have access to such material, which may be supplemented in a variety of ways – school visits, organized field trips, etc. sas is now being done in Australia. This will give candidates a much better idea of what mining is, and what to expect. On respondent suggested putting out a mining version of "Do You Want to be a Millionaire" for use in the schools, and this was a serious suggestion.

3.4 Actions Within and Between Universities

In planning this study one question had to do with whether minerals industries managers of the future would need additional skills that have not been a part of the traditional curriculum. Most respondents said yes, and the first area to be added has been the environment. Environmental considerations are now built into most mining programs. Beyond this there are many subjects in which some training would be useful, ranging from economics and business to anthropology and ethics. A major problem in making basic changes, particularly in the US, is the pressure to maintain accreditation. The mining engineering curriculum leaves little room for options and is under constant pressure to increase the technical content. There is a clear area of need and interest here, and no simple answer. Many engineers take distance-learning courses after graduation, but there are at least two other paths that might be followed.

Double Degrees: This approach requires additional time at the university. As mineral development becomes more complex the mining engineer may see advantage in knowing more than mining engineering, and programs are being developed to meet this need. As noted above, in Australia joint degrees in mining and commerce are of interest. Many Canadian universities offer joint or double degrees, and the University of Western Ontario can serve as a model. At UWO the program is called Engineering Plus, and engineering students can take double degrees in a range of subject. Normally the student receives two degrees, and the program takes 5 instead of 4 years. Thus a Civil or Materials Engineering graduate receives not only the engineering degree but also a degree in Business Administration, or Law, or French, or Economics or International Affairs. A combination with Medicine is possible, but requires 7 years for a medical degree plus an engineering degree. Students with special interests can devise their own combinations, and programs linking Electrical Engineering and Music, and Civil Engineering and Russian have been approved. Engineering students may also take a minor in sociology or ethics or business, but it is often difficult to work this in due to the very heavy load of required engineering courses. Similar combines programs are available at the University of South Australia and many other schools. (check the requirements in various mineral engineering fields under Definitions in Annex II)

Putting Courses on TV and Online

The world has moved from the Industrial Age to the Information Age, and this has serious implications for all education. A number of respondents to the survey mentioned the possibility of putting courses online and this is an area in which the mining industry is just beginning. The University of Missouri – Rolla is one of the leaders, and currently offers a 33-hour web-based Masters of Engineering degree. The course already has 10 enrollees, mainly from industry. Edumine www.edumine.com in Vancouver is dedicated to online learning, training and technical reference for mining and the geosciences. They have some 30 online courses ranging from 10-40 hours and more are under development. Courses include underground mining methods and equipment, underground mining practice, flotation, surface reclamation techniques and rock engineering.

A good model for on-line education is the National Technological University <http://www.ntu.edu/> that operates from a state-of-the-art campus adjacent to Colorado State University in Fort Collins, Colorado. NTU is one of the more advanced "virtual universities" operating in the engineering field and serves the educational needs of graduate engineers, technical professionals and managers through the use of the latest educational and telecommunications technology. It has working links with more than 50 of the major universities in the United States, and currently offers over 300 courses and 19 Masters degree programs, including one in Materials Science and Engineering. No Doctorates are offered. Most courses are delivered to sponsoring organizations at many locations in the world on the NTU instructional TV network but there is a shift towards online courses, which have grown from 1 in 1998 to 160 today. Six Masters degrees are currently offered on line. Of the 301 courses being offered by the NTU in the fall of 2001, 87 are online, 52 are on CD ROM and 170 are on TV.

> Online training is ideally suited to meeting the needs of the mining industry where hundreds of engineers, often in remote locations, wish to take refresher and upgrading courses or have time to work towards a Masters degree. This is a growth area for the mining industry of the future, and some professors are already considering putting their courses online. Working with NTU or one of the other universities that has an established record in this area would give them a strong base and a good start.

Networking of National or Regional Centers of Excellence The concept of networking of a series of universities as national or regional Centres of Excellence is receiving much thought at present, (see the above notes on the Australian and Canadian networking programs). The model used here is the European Mining Course and the European Mineral Engineering Course www.emc-edu.org that have been operating for about five years with considerable success. The EMC/EMEC programs offer Masters Degrees in Mining Engineering and Mineral Engineering drawing on the combined resources of four European universities: the Royal School of Mines in London, the Technical University at Delft in the Netherlands, the Technical University of Helsinki in Finland, and the RWTH at Aachen in Germany. Teaching is in English and students take a series of modules that emphasize either mining engineering (EMC) or mineral processing (EMEC) at each of the four universities during an eight month period, followed by thesis study at their home university. Each program accommodates a maximum of 5 students from each participating university, and, depending on available space, accepts candidates from other universities. Students from Queens University in Canada. Virginia Tech in the United States, and from Chile have attended. There has been talk of expanding the network, but based on the experience to date, it is felt that four is the right number of universities to be linked in this way. The program has been quite successful and effective on this scale.

The concept of selective strengthening of university departments to allow each to serve as a Centre of Excellence for a particular subject in a regional network within which students rotate is under active consideration. The approach may have useful implications in developing countries, or within a country such as China where there are several mining schools.

Improved Websites. During recent years we have turned increasingly to the web for information of all sorts, but the potential is there to do more. Many sites have limited information, many are not well designed, many are in the local language, and full advantage is seldom being taken of this valuable resource. Consideration could be given to preparing and making available to all schools a standard design web site for mining departments that will allow for some comparison of their programs and resources. As a first step a Directory can be compiled of the websites of mining departments, so that it isn't necessary to go through the whole search each time information is needed. Professor John Sturgul has created a section on the University of Idaho site that lists the major mining schools in the world. www.uidaho.edu/mining_school . As part of this MMSD exercise summaries of basic information on more than 250 mining programs at world universities with a link to each school's site have been prepared, and it is expected that these will be put on the website of one of the cooperating groups. This provides prospective students with an overview before they go into the site of the schools on which they wish further information and is also useful to professors evaluating candidates for graduate study. Some schools might see value in using such a summary of their programs as an introduction to the department site.

The MMSD study includes short reviews of about 250 of the main mining engineering programs in the world. These provide candidates with an overview of the programs before they go into the school's websites for details. Information on the mining schools is in a database, and, as part of the MMSD follow-up consideration should be given to maintaining this. One possibility would be to link with the University of Idaho Directory of Mining Universities <http://www.uidaho.edu/mining_school/> If the follow-up organization were to fund a fellowship at Idaho to cover this (about $15,000 for an eight month year) it would be possible to keep the Directory up-to-date and also to carry out related programs, such as compiling an inventory of online courses and of material on CD's. These are all part of the same picture, and they all fit in with what MMSD is trying to do.

3.5 Learning from the Experience of Others

In the preparation of this report on mining engineering education there has been limited time to check on how similar problems are handled in other fields, i.e. what do veterinary or forestry schools do when the demand for their services dries up? Also no thorough search has been made for websites that contain information useful to the study. Only the surface has been scratched, and more should be learned about these areas, as much of this experience is transferable. Some relevant programs are noted, but there are certain to be many that have not yet been identified.

One initiative that is relevant is the Mineral Resources Forum, part of the UNCTAD website on Natural Resources for Sustainable Development. www.natural-resources.org/minerals . As part of this program UNEP-Paris maintains an interactive minerals and the environment website <www.mineralresourcesforum.org> This site has links to a large number of related programs including those of the MMSD, the World Resources Institute, and many others. Information on this can be had by contacting minerals.forum@unep.fr These minerals-related sites might be expanded and built into the follow up program of the MMSD in cooperation with UNCTAD and UNEP. Reference has also been made to the Edumine site in Vancouver. www.edumine.com There is the parallel Infomine site at www.infomine.com The work of the Raw Materials Group in Stockholm www.rmg.se impinges on many aspects of the MMSD and should be consulted.

There has been talk of identifying and publicizing a set of "wise practices" for the mining industry. This is something that could be placed on an interactive website to serve as a basis for discussion. A model can be found in a UNESCO marine sciences website that publishes each month a case study of "Wise Coastal Practices for Sustainable Human Development." www.csiwisepractices.org A similar site on "Wise Mining Practices for Sustainable Development" could be considered. This is an initiative that could be taken and maintained by one person.

The United Nations University, based in Tokyo, established the Institute for Natural Resources in Africa in Accra, Ghana, which in turn set up the Mineral Resources Unit at the University of Zambia. www.unu.edu/Inra/index.htm The United Nations University does not offer formal courses, but through institutes like INRA undertakes regional training and research. The Mineral Resources Unit has carried out programs related to mineral fertilizers, and has the potential for other related activities.

We can learn much within our own house. Mention has been made of the many Australian initiatives, and these deserve careful attention and review. For example, note the large number of industry supported research institutes that are attached to Australian universities. At the University of Queensland alone we find the Australian Centre for Mining Environmental Research, the Mine Industry Safety and Health Centre, the Julius Kruttschnitt Mineral Resources Centre and the Centre for Social Responsibility in Mining. One of particular interest is the Sustainable Minerals Institute, a multi-disciplinary center that aims to serve as a comprehensive center for Australia and the world in research and training on sustainable development of mineral resources. Surely this is a useful model for other schools and countries.

Finally, there is one model that may be relevant for follow up. In the 60's and 70's there was a surge of interest in agricultural research and in 1971 the World Bank set up the Consultative Group for International Agricultural Research (CGIAR) www.cgiar.org This has evolved over the years into a very powerful mechanism for stimulating, monitoring and funding agricultural research throughout the world. Its programs have won international awards, and have had truly remarkable impact on the lives of millions of the world's poor. In Annex III this will be used as a model for a Consultative Group for Sustainable Mineral Development.

Follow Up

An essential element in the GMI/MMSD review and discussion is a detailed and specific Plan of Action for follow up and a mechanism to monitor, coordinate and fund this follow-up. It is encouraging to note the establishment of the International Council on Mining and Metals (ICMM) which will be a major and valuable part of the MMSD follow-up. ICMM is clearly industry based (which is its strength) and should be viewed as one important part of a set of closely linked bodies (consortium/consultative group) that will bring industry together with governments and universities to play their unique and essential roles, and will give due and equal attention to the role of NGOs and the full "community of interests" of the mineral development system. There are useful models for this (see Annex III) and we should not be trying to reinvent the wheel. We need to attach the existing wheels, to our chariot so that they are pointed more or less in the right direction and will work in harmony, then to construct an engine that will carry us towards our common destination with some degree of efficiency and dignity. Mining engineering education will be one essential package in the chariot.

The Vision

To go back to the opening sentence of this report -"Over the next 50 years the world will use five times the mineral resources that have been mined to the year 2000." If this is even close to being true, serious and concerted steps must be taken to assure the future of the mining industry, and of the professionals who service it.

As has been noted, much initiative for follow up in education and training is coming from Australia where the vision is to integrate mining engineering education under one umbrella organization that would coordinate staff and student recruitment, course development and delivery, and interaction with industry. This may not be too far from the visions at Luleå and Leoben where interest has been expressed in establishing International Centres of Excellence for the Mining Industry and in Canada where steps are being taken to link mining programs. The move towards eLearning is inevitable. It is expected that the MMSD exercise will support these initiatives and stimulate others so that mineral industry education will continue to serve the increasing needs of the world's complex and growing societies.

To end as we began, with a quote from an Australian source:" The vision should be for a global mining education academy based around a virtual university capable of servicing the cultural diversity and continuing education needs of the global minerals industry." (J.M. Galvin and P.J. McCarthy, "Mining Education – Driven by Global Impacts," a keynote address presented in Australia, October, 2001.)

Annex I: World Directory of Mining Engineering Education

As the application of technology expands throughout the world, the demand for qualified engineers in all fields is increasing rapidly. With the growth of the global economy, the demand for mobility of engineers has also increased. Information on engineering programs at training institutions throughout the world is important to students and universities as well as to employers and the various engineering societies and licensing and accrediting bodies.

The goal of the World Directory of Mining Engineering Education is help meet these needs through providing information on facilities and programs for training in mining engineering and related fields throughout the world. It is designed to help students who are considering post-graduate study to identify schools anywhere in the world at which they might wish to study. It will also provide professors who are evaluating candidates from other countries with basic information on the universities at which the candidates have studied.

The World Directory of Mining Engineering Education is an on-going project. Information has been collected from a variety of sources including the World of Learning, national and regional directories and direct contact with many of the universities through their websites and through e-mail.

To date some 275 universities have been identified that give training in mining engineering and related subjects including mineral processing, mining geology and mineral exploration. Entries have been prepared for each of these schools. Where full information is available on an institution the entry is about one page in length. Where limited information is available a shorter form is used, but as additional information becomes available it is planned that most entries will use the complete form.

It is recognized that there will be many errors and omissions in this first effort to collect information in this format. Some schools that are listed may no longer teach mining, some that teach mining may not be included and names of professors and departments may be incorrect. We offer our sincere apologies for these errors, and request your assistance in correcting them. The material in the directory will be revised and up-dated on a continuing basis, and universities offering training in the fields that are covered are invited and urged to submit changes and revisions that will make their entries more complete and accurate. Please submit suggested changes to minenged@aol.com

It has not yet been decided where the Directory will be located on the web. For the present it is at www.genatrix.com/mines/search.cfm.

Annex II: Definitions of Sustainable Development

(Adapted from Notes by Fritz Balkau of UNEP – Paris)

The concept of Sustainable Development embodies two main ideas; the interplay of economic, social and ecological priorities, and the goal of trying to develop and maintain long-term objectives while undertaking what are essentially short-term development activities. This gives due regard to maintaining the integrity of our (ecological) life support systems while protecting or enhancing the quality of human life (health/culture).

In teaching, the subject content (e.g. mining engineering) should include ecological and social as well as technical components. Students should be given a perception of an over-all system (environmental system) into which they will be able to integrate new situations and knowledge. Pedagogical methods should focus, *inter alia,* on building analytical, problem solving and communication skills in which an essential component would be basic literacy in contemporary SD languages and definitions. On the question of whether it is best to provide in-depth SD training to an elite of engineers or general training to all engineers, it appears that since the primary prevention role rests with the designers, planners and operators of the industrial systems (the mining companies), the primary vehicle for SD training should be the teachers in the traditional disciplines (the mining professors).

Engineering and the environment is in a transitional stage, moving towards a time when most engineers will be environmentally literate and some environmentalists will be engineering-literate. By that time engineers (including those working in the mineral industry) should be at the stage where they will fully embrace SD concepts and promote, implement and demonstrate preventive, multi-objective environmental actions rather than today's end-of-pipe approach. This will have clear implications for teachers, courses and accrediting bodies and will require support from related professional and business organizations.

Mineral Industry Education Definitions

Engineering Sciences have their roots in mathematics and basic sciences but go beyond this to apply the knowledge. They serve as a bridge between mathematics and basic sciences on the one hand and engineering practice on the other. In order to promote breadth, an engineering science curriculum must include not only engineering and technical courses but also courses outside the major disciplinary area. It will include elements of mechanics, thermodynamics, electrical and electronic circuits, materials science, transport phenomena, and computer science along with other subjects depending upon the discipline.

Training programs include engineering design, which is the process of designing a system, component, or process to meet desired needs through the application of basic sciences and mathematics and engineering sciences. Among the elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation. The process must take into account a variety of constraints, such as economic factors, safety, reliability, aesthetics, ethics, as well as environmental and social impact.

Mining and Metallurgical Engineering: The mineral industry is a world-wide activity involving the recovery and processing of nonmetallic minerals, metal ores of all kinds, and solid fuels and energy sources such as coal and nuclear materials. The industry is one of the major users of high-tech systems in the world. Because of intense international competition and environmental pressures, the industry is aggressively seeking productivity improvements in many areas including automation technology, robotics and computer aided design, and is one of the major components of globalization. The importance of ecological and environmental planning is given strong recognition and increasing attention in mineral development and mineral industry education.

The administrative lines drawn between the mining and metallurgy departments at universities vary considerably. Some schools group all engineering subjects in a "College of Engineering." Others separate the mineral-oriented disciplines into a "College of Mines." Some schools group applied geology and geophysics with mining and mineral processing under a Department of Mining Engineering. Extractive (or chemical) metallurgy and process metallurgy may be grouped with physical metallurgy in a Department of Metallurgical Engineering, a Department of Metallurgy and Materials Science or, most commonly today, in a Department of Materials Science and Engineering. Some schools maintain three divisions: mining, mineral engineering (which includes mineral processing and extractive and/or process metallurgy), and metallurgy-materials science which emphasizes the structure, fabrication and utilization of materials including but not restricted to metals.

Mining Engineering includes elements of geology, chemistry and physics as well as civil, mechanical and electrical engineering and the social and environmental implications of mineral development. Students apply scientific theory and modern technology to the development, evaluation and recovery of mineral resources from the earth as well as to areas such as the construction of roads, tunnels, underground waste disposal chambers, etc. Subjects in the mining curriculum include *inter alia* principles and techniques of mineral exploration, mining methods, mine planning, mine design, surface and underground operations, rock mechanics, rock fragmentation, materials handling, safety, environmental impact analysis, mineral or coal processing, mine surveying, mine valuation and mine rehabilitation.

Mineral Processing may be dealt with partly in mining and partly in metallurgy. It deals with the processes that are applied to coal or ore immediately after it comes out of the mine. These include crushing and grinding (comminution) and some types of concentration, e.g. gravity or magnetic. Mineral processing plants are normally at or near the mine site. Processes that require actual decomposing of the ore are normally taught under metallurgy.

Metallurgical Engineering deals with the processes that turn mineral raw materials into final products including processes that turn ores into metal products. Such processes cover comminution and concentration which may be partly dealt with under mining, as well as extraction, refining, alloying, and forming. They include flotation, solvent extraction, hydro-, electro-, and pyro- metallurgy (extractive metallurgy) as well as the treating and forming metals by rolling, casting, joining, welding, drawing, etc. to transform them into a useable shapes and forms (physical metallurgy).

Materials Science and Engineering deals with the science and technology of producing materials that have properties and shapes suitable for practical use. Fifty years ago most of these materials were metals, and emphasis was on metallurgy. Today materials include metals, ceramics, polymers (plastics) and their combinations called composites. Activities of materials engineers range from materials production to recycling, and include the design, development and processing of materials suitable for use in fields such as aerospace, transportation, electronics, energy conversion, biomedical systems, etc.

Annex III: MMSD Follow-Up – An International Union of Mining Organizations?

How do we sustain the impressive momentum that has been built up during the Global Mining Initiative/MMSD set of exercises? What steps should be taken to establish and maintain a continuing international program for mining and sustainable development that would include and draw upon the interests and potential of all of the "communities of interest" in the mineral development system? How can we create a suitable framework? Following are some thoughts on these questions.

Many sectors that work internationally are served by an NGO that represents them at international meetings and serves as a spokesman, or, where appropriate, a lobbyist for the sector. The fact that the Global Mining Initiative created a new body (MMSD) based within a group that is not directly related to the minerals industry (IIED) indicates that there is no recognized international body in the mining sector that can be called upon to play a lead role in initiatives such as this. This may be the appropriate time to create one -- an International Union of Mining Organizations.

At present there are two international groups, the World Mining Congress and the Council of Mining and Metallurgical Institutions, but they have limited mandates and impact. The World Mining Congress www.wmc.org.pl held its 18th Congress in Las Vegas in October of 2000 during the life of the MMSD but this was not widely publicized even within the United States. The Council of Mining and Metallurgical Institutions, an outgrowth of the former Commonwealth Council, will hold its next meeting in Australia in May 2002, shortly after the MMSD Toronto meeting. It does not appear to have been directly involved in MMSD activities, although member bodies of the Council such as the CIM and the SME may have been.

In considering how to deal with MMSD follow-up there are two international NGO coordinating groups working in related areas that can provide models, the International Council of Technical Associations and Organizations (UATI) and the International Council of Scientific Unions (ICSU). These are umbrella organizations that support, link and coordinate the international interests and activities of the various technical and scientific organizations in specific fields or sectors. They work closely with the UN (mainly UNESCO) and provide the UN and the professional public with high-level access to the world scientific and engineering communities. They also serve as a mechanism for carrying out program activities within their areas of competence.

The International Council for Science, the new name for ICSU, links 26 international scientific bodies such as the International Union of Geological Sciences (IUGS) and the International Union of Geodesy and Geophysics (IUGG). The International Union of Technical Associations and Organizations (UATI is the French acronym) links 28 international technical bodies such as the World Energy Council and the International Society for Photogrametry and Remote Sensing. There is no member body of UATI or ICSU representing mining, and it is on this level that an International Union of Mining Organizations (IUMO} might be established to represent the mining community internationally

A possible mission statement for the IUMO might be:

> The International Union of Mining Organizations, through international cooperation and research and in partnership with related national and regional research and development groups, both governmental and non-governmental, will promote and work towards sustainable development of the world mineral resources based on environmentally sound production and management practices, in ways that enhance the well-being of all people with special concern for the needs and interests of low-income people in developing countries.

The closest present body to the proposed IUOM is the International Union of Geological Sciences (IUGS) and it can be used as a model. IUGS is one of the largest members of ICSU, has its own small secretariat, hosted by the Norwegian Geological Survey. IUGS has 112 member countries, (in many cases represented by the national geological survey), 10 commissions that deal with topics of concern to the membership, and 36 affiliated organizations. In the case of the IUGS, some of these are close to mining, such as the International Society for Rock Mechanics, the International Association on the Generation of Ore Deposits, and the Association of Geoscientists for International Development. IUGS is a very successful NGO. The list of "individuals cited" on its website is a Who's Who of the world geoscience community.

Even as ICSU is the umbrella for scientific organizations such as IUGS, the IUGS is in turn an umbrella over the geoscience associations. Creating international groups such as the IUGS requires initiative, and UNESCO has played a role in the formation of many of them. However, due to the idiosyncrasies of the UN system, mining and much of engineering fall outside of the mandate of UNESCO. Mining comes under the UN Secretariat, and UN mining programs are run out of New York where there is little tradition for creating parallel NGOs. Today the UN mining program is very limited, and can provide limited initiative or support. Thus it is suggested that the World Bank might perform a useful catalytic function.

The World Bank has a positive history in mineral development, including the Collaborative Group for Artisanal and Small-Scale Mining and the World Mines Ministries Forum. The bank has a credible presence in the field and a professional staff with much relevant experience. One of its major successes was the setting up of Consultative Groups in Agricultural Research (CGIAR). A World Bank initiated Collaborative Group on Sustainable Mining with a mandate to set up an International Union of Mining Organizations is one approach that might be considered.

There is considerable experience in the construction of mechanisms to promote and monitor regional and international NGOs and for such a meeting the Bank can call upon the top resources in the world.

Following the IUGS pattern, but with greater involvement of industry, a new mining Union would serve as the umbrella for existing international groups such as the ICMM (industry), the World Mines Ministries Forum (government), the Society of Mining Professors (academe), and would have working links with the Council of Mining and Metallurgical Institutions and the World Mining Council. International bodies representing NGOs, trade unions, mining communities, indigenous peoples and other communities of interest would be fully involved, and in some cases might have to be created. Affiliates would include existing international technical bodies such as the International Society for Rock Mechanics and regional groups such as the ASEAN Federation of Mining Associations in Southeast Asia. As is the case with the IUGS, the IUMO would have international working groups and committees dealing with the mining concerns and implications in areas including policy and planning, education and training, dissemination of information, and more specific areas such as recycling, land rights, reclamation and rehabilitation, small scale mining, mineral statistics, etc.

In most countries the national members of IUMO would be the national mining association or Bureau of Mines, but in some cases a national union of mining organizations might be established modeled on the IUMO. In the case of IUGS the national geological survey is often the 'adhering organization' or national representative but in larger countries special groups have been set up representing the cross-section of geoscientists. In Australia this is in the Australian Academy of Science, in Canada it is the Canadian Geoscience Council and in the US it is the US National Commission on Geology in the National Research Council.

IUMO national members should be identified with great care as mining has many "communities of interest" to be represented. It is estimated that in the United States there are more than 100 organizations that are interested and concerned with mining, and in Canada and Australia more than 50. (for a listing of existing mining organizations go to www.mining-technology.com and click on Industry Organizations.) Using Canada as an example, the objective would be to establish a Canadian Union of Mining Interests with representation, *inter alia,* of industry, government, universities, trade unions, finance, mining communities, mining associations, indigenous peoples, NGOs both pro and con, and the interests of minorities, women and children. Initiative for setting up such a body would appropriately come from government and the universities but it will be much easier to achieve with the IUMO as a model.

The first step on either the international or the national level is to set up small but representative planning committee to identify alternative paths and prepare proposals. There would be advantage to having the international committee based in a somewhat neutral environment, possibly at UNCTAD (Geneva) or UNIDO (Vienna). It might be appropriate for a representative of ICSU (IUGS) or UATI to serve in an advisory capacity.

One Additional Note

The proposed International Union of Mining Organizations has an advantage over most organizations that currently exist, because it can be designed to take full advantage of today's information technology. Over recent decades NGOs have adapted to the computer age with considerable success, but most were established before that technology was available. Today it is possible to build the latest innovations in information technology, along with some awareness of where it is heading over the coming years, into MMSD follow up. Information specialists should be involved from the beginning, the database should be at the heart of the organization, and the Webmaster and his/her team should be key players now and in the future.

Consider the potential of a computer based multi-dimensional interactive matrix bringing together information on all resources devoted to research related to mining. It would be possible to identify not only the whats, whos, wheres and whens but also how activities can be linked to promote better efficiency and to supplement one another and to identify critical gaps

On the user level, we are well on the way to a wireless web where we routinely make use of a wide range of Internet-enabled devices including cell phones, hand-held computers and even game units to access and input information. This can be built into the design of the IUMO, but it should be done with care and understanding to take advantage of the very real benefits of ICT while minimizing the costs, monetary, human and intellectual.

> Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it is the only thing that ever has.
>
> Margaret Mead