Opening Session

Welcoming Address

by Professor D. D. HOWATT President of the South African Institute of Mining and Metallurgy

Because the President of the C.S.I.R. and the President of the S.A. Council for Automation and Computation are, unfortunately, unable to be here to welcome the guests, Mr. van Rensburg has asked me, as President of the South African Institute of Mining and Metallurgy, to do so. When I began to think about what I would say, the first thing that struck me was that most people of my generation, whether in industry or the universities, have rather mixed feelings when confronted with computers.

There is the story about a man who had a very large and very badly behaved Alsation dog. One day he decided to take it to the dog training school. After a very long struggle with the dog the instructor suggested to the man that he should take it back home and keep it there until he and the dog had decided which of them was going to be the boss.

Sometimes I have just a little niggling fear in the back of my mind that we have got to sort out this problem of the computer and man, and decide who is going to be the boss. However, I hasten to say that although there are many like me associated with mining industry in this country who are not very sure what all the possibilities are, we are quite convinced that our industry can only benefit by knowing more about the application of computer methods in the mineral industry. Even with the higher price of gold in the world today—that is, outside the banking sphere, of course—our mineral industry has to be keenly interested in all methods by which operating costs can be reduced or at least stabilized—and I am sure Mr Shilling will agree with that—and greater efficiency achieved.

We welcome very much any opportunity for developing closer ties with the mining industry everywhere, particularly in North America and in Europe, and this Symposium provides a wonderful opportunity for a get-together and exchange of ideas.

We are particularly glad that this first meeting of APCOM outside of the North American continent is being held in this country of ours.

My own Institution and the two other sponsoring bodies are very glad to be associated with the American Institute of Mining and Metallurgy, the Canadian Institute of Mining and Metallurgy and those distinguished universities in the U.S.A. and Canada, who have sponsored these symposia in previous years' and in that connection we are very glad to welcome here today some important representatives from these bodies. We have on the platform Mr Weiss, Mr Fox of the A.I.M.E. and Professors Griffiths, Elbrond and MacKenzie.

The weather has not been kind in the last few days but today you are really seeing sunny South Africa, and so, distinguished guests from the U.S.A., Canada, Australia, the United Kingdom, France, Germany and Portugal and other countries beyond our borders, we bid you welcome to the APCOM symposium and to our wonderful country.

Opening Address

By Mr J. W. SHILLING President, Chamber of Mines of South Africa

Mr Chairman, Ladies and Gentlemen,

Most of you will consider it trite for me to observe that over an average working life of some 40 years most men are exposed to a variety of social, technological and other changes for which their early education and training have not prepared them. I believe that my generation can say this with feeling. Since 1930 when, as a boy just out of school, I took up a seat in the back row of life's orchestra, there have been changes that are probably unprecedented in any comparable period in the world's history. Because many of these, if not most, are in the technical field, those with technical training are favourably placed to comprehend them, even if they are often unable to explain them in comprehensible terms to those of us who may have some slight ability in other directions. In the matter of social changes, however, technically trained men find themselves reduced to a common level with less important mortals who live and have their being in other spheres. They have the same difficulty in adapting to changes in family relationships; in dealing with the spin-off of the new permissive society and in accommodating themselves, particularly in the office, to the new sartorial whimsicalities of some of our colleagues and subordinates.

Indeed, the changes to which we have been exposed over the last 40 years are so great and so far reaching that it is delightful to find that there are still parts of the country not polluted by detergent foam or sulphur fumes; that there are still places where one is not exposed to the unpleasant aspects of television and that it is still permissible to plan a garden without having to justify its existence by an acceptable discounted cash flow.

I have in my home a fearsome looking volume entitled 'Hutchinson's New 20th Century Encyclopedia'. The blurb on the cover describes it as – and I quote – 'a first-class all-embracing reference book which puts some flesh on the bare bones of fact' – unquote. How this imposing tome comes to be on my shelves is an unsolved mystery, but in it the word 'computer' appears between two references that, by the spin of the wheel, are amusingly, yet significantly, part of today's scene, just as the computer is. The first is a reference to Ivy Compton-Burnett, born in 1892, whose novels relied on dialogue – a familiar word today – to put over the reactions of small groups dominated by family relationships. The other is to Anthony Comstock, described as an American agitator who, nevertheless, founded, in 1873, the New York Society for the Suppression of Vice, Improper Literature and Indecent Pictures. And in between there appears the story of the computer, the first of which, made about 30 B.C., was recovered in 1953 from the wreck of a Greek ship found at the bottom of the Mediterranean.

Although their origins may go back to the Greek civilisation, computers and their applications have played a significant part in the amazing and almost, at times, frightening achievements and changes of the last two decades. The language of computers is the language of 'Let's go to the moon and come back'; it is the language of youth; it is the language of the future until superseded by the language of a new youth. The fear of computerization is the fear of loss of identity: fear of the unintelligible print-out: fear of the loss of humanity in personal relations. In accepting computerization – as we must and should as part of the shifting scene – what we have to ensure is that computers are used for the benefit and not the detriment of our civilization.

This is what your symposium is all about. A symposium to pursue ways of using computerization for the benefit of the mineral industry.

I understand that this is the first time such an international symposium has been held outside North America. We are honoured by the choice of South Africa as the venue and by the presence of so many distinguished guests from overseas. May I add to the welcome already extended to you, a sincere welcome from the Chamber of Mines of South Africa whom I have the privilege to represent here today. South Africa has strong links of long standing with overseas mining industries, particularly Commonwealth countries and in North America, which, certainly in the early years, contributed materially to the mining concepts now followed in this country. A happy by-product of this Symposium will, I hope, be the renewal of old and the establishment of new friendships between the countries represented here at this time.

Mining engineers are, of course, still the essential technical experts of mining, but other experts have joined them as mining has undergone great technological changes, and amongst the foremost of these today are the men skilled in computer applications.

The new tool of computer simulation promises to revolutionize the application of mining techniques in this country, and we are investigating many other uses of computers in mining besides.

A recent survey conducted by the Council of Scientific and Industrial Research on behalf of the Prime Minister's Scientific Advisory Council showed that annual expenditure on applied research and development by private industry in South Africa was R11,2 million.

A total of R5,78 million, or almost 52 per cent, was spent by the mining industry. The South African mining industry is therefore revealed as by far the most active and enterprising section of South African industry in this respect.

This expenditure on research is, of course, partly forced on us because our industry is the world's main centre of deep-level mining practice and we must do our own experimentation if we are to mine deeper still.

But in addition it reflects the determination of our mining industry to maintain its place as one of the great centres of mining technology.

In the comparatively recent past we have broken world records for tunnelling and shaft sinking. Our expertise is sought abroad and South African mining engineers have sunk shafts in many countries. Not the least of our achievements was to keep a massive gold mining industry in operation in spite of a 35-year freeze of the official gold price in terms of dollars.

We know that computer applications offer some of the most exciting possibilities of the new world of mining, and we intend to be well up in the world race here, too, where we can, in those fields which give us scope to do so.

For the sake of our many overseas guests, may I briefly outline the organization of the mining industry in this country,

an organization which enables us to plan on a large scale and make the best use of available skills, including the skills of our computer experts.

Because the gold-bearing reefs on the Witwatersrand are low-grade and deep-running, the principal factor when mining began last century was large-scale finance. So mining finance houses quickly dominated the industry.

Very quickly what we call the Group system evolved, with each large mining finance house providing finance, technical expertise, secretarial services and much else, for a group of mining companies. This made possible the raising of finance and the best use of skills in a country short of these commodities.

Eventually, as gold mines became even more enormously expensive to bring into operation, several mining finance houses often combined to spread the risk. It is an interesting thought that computers are now carrying this diminution of risk a step further, for by means of investment and financial analysis by computer is is now possible to analyze the risk of opening up an extensive new mine more accurately than ever before.

The Chamber of Mines was a natural outcome of the gold mining industry's philosophy of co-operation. Tasks which can be better performed on an industry basis than on a mine or Group basis are the function of the Chamber of Mines. These functions include negotiations with nine trade unions, the recruiting of labour, including over 300 000 Africans each year, and, more recently, large-scale research into new methods of mining.

The cost of this research would be beyond the means of individual mining companies and is, of course, for the good of all.

The Chamber of Mines represents about 98 per cent of all gold mining in this country and over 80 per cent of mining of all types. It is in many ways a unique body arising from a unique situation which was that most of its major members do not compete in the sale of their product, gold, and can therefore co-operate to a degree unknown in most industries.

The Chamber, for example, provides a clearing house for technical 'know-how' and machinery for close co-operative examination of technological matters, like the application of computer methods to mining in South Africa.

South Africa does not have the range or extent of computer facilities available in the United States. This is not altogether a disadvantage. It has meant that our computer men have had to think hard about the effort they put into computer applications. It means we have had more time to see what computers can do and what their applications are before we buy them.

There is a great deal to be said for having plenty of experience under one's belt in any field using conventional methods, before moving on to investigation of the possibilities of more sophisticated equipment. That was our experience in ore valuation where pioneer work here in statistical theory over many years led directly to most valuable computer applications in this field.

In other areas our computer experts have brought about impressive changes in mining techniques, especially in the field of rock mechanics.

The solution of technical problems involved in deep-level mining, particularly thermal and strata control, already owes much to computer techniques.

Analogue and digital computer techniques have been developed to assist planning so as to ensure minimum risk from falls of ground induced by rockbursts. It is a tribute to the effectiveness of these techniques that almost without exception today the advance planning of our deep mines is carried out using them.

Organizational problems of the mining industry's research programme, and particularly those relating to the underground operations of gold mining, are so large and complex that the application to them of conventional research methods has been possible only in a restricted number of cases. The development and increasing availability of digital computers, however, has made them susceptible to study by simulation methods.

This has been taken up actively in the past two to three years with the result that a computer program, simulating a complete sequence of underground gold mining operations, is now becoming available to mine managements. Programs of this kind have very great potential as management tools, since they enable managements to investigate, analyze and compare the relative merits of different mining systems rapidly and cheaply.

Simulation models offer a method of overcoming one of the principal obstacles to innovation and development in gold mining which is simply the time, the costs and the risks involved when new procedures are tried out underground.

In the field of colliery operations, which tend to be simpler than that of gold mine operations, we have recently completed the programming by computer of the complete operation and future planning of one colliery.

It is clear that the usefulness of such a complete simulation of a mining operation is very considerable, and one can say with confidence that simulation by computer is destined to become an increasingly important attribute of all mining in the future.

In other fields of mining in this country the computer has been of great use for a number of years. I refer to the commercial computer applications like the processing of wages, salaries, pensions, sales accounts, statistics and so on. But, of course, it is in the field where computers make calculations which could not be done manually, which thus open a large area of possibilities never before envisaged, that the exciting possibilities lie.

In this area computer science has been active in South African mining for less than a decade.

The theme of this symposium is the application of computers in mining, not the development of computers as such. Their development in mining depends very much on our human resources and the degree of co-operation received from those in authority in the mining industry. And that, of course, depends on the degree of knowledge in the mining industry about the possibilities of computer techniques.

The object of this Symposium must be to help key people in the mining industry become more familiar with computer applications. If it can show these people how best to apply computer techniques to mining and how to use computerization to solve mining problems more quickly, and if it can show how computer techniques can solve mining problems that were not soluble before, it will have been well worth while.

If, in addition, it can inspire our computer engineers and scientists to seek new ideas and new approaches it could mean for South Africa safer mining, more mining and more economical mining still.

I wish you all a stimulating Symposium and now have great pleasure in declaring open the Tenth International Symposium on the Application of Computer Methods in the Minerals Industry.

Keynote Address: Economic and Financial Modelling

By Mr K. F. LANE—Director, Rio Tinto Zinc Corporation Limited, London, England.

I would like to say what a pleasure it is to be here today.

I first started prospecting among the literature on computer methods in mining some time in the late 1950's and this was a pretty barren exercise at the time.

It certainly would not be now, largely as a result of the series of symposia which have been held in the last 10 years, but what struck me particularly at the time was that if one was looking for authoritative papers or authoritative information on sampling statistics and ore reserve estimation, then most of these papers originated in South Africa. Now it seems to me that this lead that was established here during the 1950's has been retained during the 1960's as well. I regard the holding of this Symposium here in Johannesburg this year as very much a tribute to people who were concerned in those early days for the quality of the work which they did.

Now, against that background I consider it a privilege to have been asked to give this keynote address today. My subject is to be economic and financial modelling, and what I would like to do is to illustrate our experience within my own Company with economic and financial models over the last 10 or 12 years. I think with some of you this may strike a note of sympathy and for others it may be some kind of guide to the sort of problem that you encounter when you start trying to do this sort of thing.

I think 'modelling' itself is a very unfortunate word. It is often, unfortunately, all too apt. It implies toys and playing at games and one does therefore have to emphasize all the time that what one is trying to do is to be of some use to one's organisation or of use to the industry in general and not just amusing one's self with computer models.

I would like, first of all, to say something about the purpose of modelling so that we will understand what it is all about. In order to do this I would like to give by way of an illustration an account of the first occasion on which I got involved, not in computer modelling, but in the modelling situation in the mineral industry. This was back in the early uranium days, when my Company was particularly concerned with uranium in Canada, which is one of your main competitors, I understand. At that time, of course, mines proliferated because everybody being in a state of some euphoria, thought that uranium was going to replace oil and coal as a fuel.

So mines were opened up, across the world, with a large number of them in Canada, and my Company finished up with interests in about seven producing mines in the Elliott Lake area. These mines had amongst their assets, first of all, the mine itself, of course, the particular ore reserves at particular estimated grade, certain installed capacity at which they could produce, a certain financial position which could be described in terms of the loans and loan obligations they were supposed to meet and also, of course, very important, a particular tax position. Also you had things called tax credit which you could accumulate, particularly if you were not very profitable.

The contracts at that time were parcelled out through Eldorado, which is a Canadian Government organisation, to the mines and the contracts were made unique to each mine, that is to say, every producing mine had a contract and it was a contract for the supply of uranium largely to the British and American governments for certain fixed tonnages and prices. The particular point about these contracts was that they were totally non-transferable.

As the picture gradually unfolded, because of the tremendous rush there was at the time, which is very familiar in mining, a number of the mining installations proved to have been grossly over-extended and some of them gradually got into difficulties, when it became apparent that the original contracts were all they were going to get in the foreseeable future and that any ideas that they had entertained earlier about being able to sell large quantities of uranium over and above the basic contracts were not going to materialise. Indeed ever since then they have been very slow to materialise as some of us are well aware. Because of the difficulties some of these mines were encountering in about 1959 or 1960, the non-transferability of contract was relaxed, that is, when it became possible to interchange contracts and they could actually be bought and sold. Because of these developments, it was possible among the mines in which we had interests, to consider rationalization. By rationalization I mean the idea of merging, take-over, transfer of contract, transfer of tax losses, etc., in order to exploit situations to best advantage.

So we had a position where we had some mines with known ore reserves, known tax position, known contract, and we could shuffle these around in order to come up with what was, hopefully, the best solution concerning levels of production with the possible closure of some mines.

When you are faced with this kind of planning decision you do not really have very much time because if you are talking about amalgamation and mergers and so on, the whole question is very sensitive as far as the stock exchange is concerned; so you have to work against pretty tight time schedules and you have to keep everything highly confidential.

I guess many of you have gone through this kind of experience, in which you had to work out for each mine through each year the likely cash flow position for different combinations of mines' production levels and a different means of distributing these contracts. A group of three or four of us spent, I would think, several months working manually, filling in acres of traditional accounting sheets. At the end of it all we came up with a particular combination and we formed a new company into which these other mines were put according to a certain sequence and that is the company which still represents our interests in Toronto.

I think a number of us who had some familiarity with computers before this time concluded from this kind of experience that a computer model would have been of tremendous assistance. Not only would it have shortened the time involved in making these investigations, it would have reduced the amount of work that we had to do and it may also have enabled us to find a better solution because we crossed out a whole number of possibilities simply on the grounds that we did not have time to investigate them anyway.

It is this kind of position, which, to my mind, illustrates the area of application for economic and financial modelling, and this is the kind of thing I have in mind when I talk about economic and financial modelling. What we are considering is a planning tool and to be successful it should

be a tool which the planners, or the company executives, use in order to reach their planning decision more efficiently.

Not long after we had the opportunity to produce a model, appropriately, I think, in view of the location of this Symposium, in relation to our Palabora project. The early planning for this mine was done in 1961-1962. We were concerned at the time to establish the combination, I can use the word 'optimum', everybody uses it, I do not trust it much, but let us use it, optimum combination of size of concentrator, scale of mining, by which I mean the tonnage that we were going to take from the pit, stripping and the grades of ore.

In order to do this we built up a representation of the ore body and our information on the ore body was very good. Of course, one of the advantages of open pit mining compared with deep underground mining is that the information that you have about the ore reserves is very much better. We represented this as a sequence of grades that would be available over time as we mined through the pit, and in addition to this we had estimates of the capital cost for different scales of mining and of operating costs. Around all this we constructed a special program, which we called the Palabora Evaluation Program, PEP, and we used this on-line.

In the event, I think perhaps we were exceedingly fortunate with the timing. The program was developed and tested in London. It is a very elementary kind of program and it would not impress you at all today. We then had a series of meetings in Toronto and I think it was in this sense that we were fortunate. A lot of the engineering know-how was centered in Toronto. Since Palabora was a joint venture we had to have fairly formal executive meetings in order to progress the whole project. These formal meetings were held in Toronto and a number of us who were concerned with the planning attended these meetings.

The drill would be that during the course of the day we would have a round-table discussion about the information that was available to us, the possible design criteria, the scale of mining and financing insofar as we were able to understand the way in which the financial possibilities were evolving. During the day people would make comments, such as 'surely if we do this we might be in difficulty in five years', and 'what happens if copper goes down to £180 a ton?' We accumulated all these comments and questions, and we also put together the suggested modifications that anybody floated during the day or at least those we thought we might take seriously. Then, because the engineers were also in Toronto, we were able to get fairly rapid estimates as to what would be the cost consequences of these suggestions. We ran along (I think Toronto University was where we were able to locate a machine in the end) and sat up overnight with some students who were there, fiddled about with various things, put the information together, ran it through the machine and, on those occasions when we were exceedingly lucky, the next morning we had a whole lot of output which we edited a bit and then went along to the meeting, hopefully with the right kind of answers to the questions that had been raised the preceding day.

Now I do not have to tell you that it did not always work that way. We had a lot of running problems on the machine. We had about two or three weekends during the course of the work for which we were very grateful because it gave us a couple of days in which to try to catch our breath so to speak, but nonetheless in the midst of all this it worked, indeed, very impressively, I think.

The kind of questions that people will ask when they are discussing a project of this kind and the sort of things that worry people when they say, 'it is all very well talking about a grade of 0,4 instead of a grade of 0,3 but what is that going to do to the life and what is that going to do to the waste ratio and what is going to happen to our profits five years hence?' and so on – to be able to come along the next morning with something that was an answer, albeit a fairly approximate answer, helped the evolution of thinking tremendously, I think, and the whole approach really geared in to this sequence of planning meetings very successfully. We learnt a lot and that gets me onto the next stage of development in our company.

I would like to say in passing that we have worked with this word 'optimum', but we certainly did not get anything that looked like an optimum in any sort of economist's or mathematician's sense. We did demonstrate, I think, the tremendous economic significance of, firstly, cut-off grade and, secondly, the scale of the total installation, both of which subjects have been pursued subsequently, and there is quite a lot of literature on them now. But an overall optimum we certainly did not get. An interesting point to my mine, which has been repeated subsequently a number of times, is that the size of the installation that you install in the end depends on how much courage you have got and not much else. You can investigate this question of optimum and all you find is that the larger you make an undertaking the better it looks and so therefore you get to the point when you ask, well, can we really raise that sum of money and stand behind it, and is it really feasible to manage something that enormous? That is really it, simple courage.

Now after the Palabora application, a lot of computer people who were involved, naturally got very enamoured about the idea of trying to generalize the program that we had. It was of use only to Palabora, and as soon as we wanted to start with something else, we had to re-write it. Now that did not seem to be a useful thing to do, so we then went on to the idea that we would introduce a much more generalized financial evaluation program. As a result of the Palabora experience, there were, I think, three particular characteristics that we wanted to build into it.

Firstly, the form in which the information is fed to the program has simply got to be as simple and as flexible as possible. The point about this is that if the program is going to have an on-line application, that is to say, going to be of real use to the planners, then you are working under pressure of time and this is at best irritating, and at worst it is a prolific source of error to have to adhere to elaborate sets of input rules. I am saying something with which, no doubt, everybody here will be very familiar.

Secondly, the program itself must be either very powerful or else be easy to modify because it is exceedingly difficult to anticipate the demands that will be made on it. Any of you who have had a go at trying to develop generalized programs will recognise the truth of that particular observation. It does not matter how general you think you have made it, the first time you try to apply it, somebody will find some peculiar gimmick that it will not cover.

Thirdly, the output must also be flexible and offer the possibility of a high degree of selectivity in order to avoid the problems of searching through reams of paper and unmanageable masses of figures. Well, again I guess you will all be fairly familiar with that. You have to be quite ruthless about this in my experience. I also find very disappointing, even if you have built in considerable flexibility and considerable selectivity, the extent to which the users, for some reason or other, will ask for the lot, which gives you great stacks of paper, so that really all you have done has been to transfer the problem to one of searching through these stacks of paper instead of doing original calculations.

The kind of program that we produced at this stage, and I am talking about 1964-1965 now, was largely a financial one, so we could put in the information about a particular

situation on the project, think about capital costs, operating costs, information about the financial status of the project in terms of loans, loan commitments, loan obligations, the equity position, tax, royalty – all these variables could be fed in and they were handled virtually automatically and the style of output obtained was virtually automatic. But we had to leave a hole in the middle of the program. At that stage we never could resolve the problem of modelling any particular application, so we left a gap in the middle as far as the rules governing the particular model were concerned, so anybody wanting to use it had to pick up the package but had to write his own little bit of program. Now we found that usually in some fairly normal application, this took just several days. It was not an elaborate problem because all the ground work had already been established but you did have to do this little bit of work before you could use the program.

Now this program, which we called 'financial evaluation program', has gained a fair measure of acceptance throughout the Group, and has been used quite widely. In fact, even around 1965, our program was incorporated into our 'Property and Financial Planning Manual' as I think it was grandly termed, for the whole of the RTZ Group, and this manual tells you all the accounts you are supposed to keep and what you are supposed to report to Head Office and so on, and at the back of it it had a complete write-up on the financial evaluation program on the supposition that companies in the Group would want to use it. Some of them have, too.

I mentioned in passing that the program has had quite a large variety of applications. One of the most spectacular was, perhaps, our Hammerley negotiations in Japan where we had a group sitting in Japan negotiating iron ore contracts with the Japanese. The time difference between the United Kingdom and Japan happened to work in our favour because our Group in Japan telexed the latest suggested set of conditions back to the United Kingdom. These were run during the day and we telexed back to Japan in the evening, so they got them the following morning and then argued on the basis of the evaluations that we had given them.

Since 1965 this program has grown in all directions into an almost unrecognisable animal, but all I would like to do, instead of pursuing any of these developments in detail, is to summarize the different avenues of development since then.

The first is this question of ease of application. We had this specially written program, and of course people always objected to it. The programmers themselves objected to it on the grounds that it was not a nice, elegant piece of programming to leave a hole in the middle, and the planners objected to it on the grounds that they needed to be able to program otherwise they could not use it. So we have endeavoured to produce a number of general programs in order to avoid this question of programming. I think, perhaps, we had some success with this but we found in practice that unless you have a fairly complex routine you do not really achieve any degree of generality, and if you have a complex routine in any sense, you have to produce a user's manual. We have found that planners in general do not like user's manuals any more than they like programs, so manuals have not really got us anywhere. I think this is still very much a difficulty with computers. We have not got to the stage that one has with a car, for example, where it is quite possible to learn how to drive without knowing anything about the mechanics of the car itself.

The other possibility which is really allied to the first is the idea of introducing greater power and producing a program that is much more general and much more capable of being applied to a large variety of industrial situations. Now, we have given a lot of attention to this and we have put a lot of effort into it with, I think, a fair measure of success. We have one particular general program, of which we are rather proud and we have applied it successfully in a number of instances. As I have already mentioned, the problem that you run into is that the controls that you have to supply to somebody in order to use this program are themselves so involved that you wind up with the user's manual which looks like a book, so that although no programming is necessary to use this program, nonetheless a fair amount of hard work is. You have to have a user's manual, you have to study it, you have to know what the options are and you have to know how to choose these options. So for this reason I think we still have not really been successful in producing something that you could call a do-it-yourself planner's modelling instrument.

A third possible line of development is the permanent data base and indeed we have done something on this. The thought here is that you accumulate a whole lot of information about your company describing its present position and even describing its future plans to the extent to which they are fairly firm future plans. If you keep these data in some enormous data bank and whenever you want to consider a project against this kind of background, you can plug your system into this data base and it can recall all the information you want and use and grind out five-year plans and so on. This we are still working on and it is proving to be a much more elaborate enterprise than we ever originally anticipated. I think the special difficulty here is the whole problem of data retrieval and this can become extremely expensive, precisely because of the problem of anticipating what kind of data you are going to want. In order to insure themselves, people will over-estimate and put in every kind of detail and in no time at all you have got something that is very elaborate.

Better output format is the fourth direction in which development can be made. I have already commented about the importance of output format. We found in this connection an irritating and a quite ridiculous problem in some ways. One of the largest applications of our programs was a tremendous financing operation and as part of this we had to submit very detailed schedules to all institutions who were going to support the project and help us to raise money. We found that when we did the obvious thing, which was to put together some of the computer output schedules into little booklets that we could send round the institution, we got any number of reactions from these institutions because the totals did not reconcile. They did not have any comments as to whether the capital estimates were accurate and on all the other things that surrounded the project, but they did point out that on page 24 if you added the figures up the total was one different from the total on the bottom of the page. This might sound really amusing but it was a serious issue indeed that was not acceptable in the end and we had to re-process all this output manually and retype it in order that when it went round to some of these institutions, the figures added up properly and they did not have to worry. You see, it undermines the credibility of the whole approach if you cannot even add up right.

The fifth direction of development that I would just like to mention is more sophisticated analysis. There are a number of directions in which progress can be made and indeed they have been covered in past symposia and I think they will be covered in this Symposium. One is the whole idea of risk analysis, that is, the idea that you can get the program to generate a distribution of present value or something of this kind which will give people a better understanding of the risk involved. Another area is optimizing models and why do we grind through all these alternatives, why do we not just build something inside the machine and grind through them first? Both of these I regard as something very much

for the future, although I am looking forward with interest to other people's experiences.

Concerning probability distributions, we have found that we cannot get these out of the people who supply the estimates in the first place. I have already commented on one instance which illustrates this point very clearly, namely, the copper prices we took at Palabora. We actually investigated Palabora, I think, at a range of prices from £220 per ton to £250. I think somebody suggested rather wildly that we might even go to £260 or even £275, but you see as long as you are dealing with ranges of figures like that, which really do not relate to what might happen in the future, you do not have any basic distribution to work on. Engineers, of course, if you ask them what are the estimates of probability surrounding their capital cost figures, look at you affronted. Also, we find that if you write any kind of report to our board which says anything about probability distribution, they will not even begin to look at it.

So we are really non-communicative on this front altogether, but although we have done a certain amount of work and, indeed, to some degree have used these figures to help make up our minds, we have not found that we can make it part of an operational system.

On the optimizing of models, firstly, the optimization is usually exceedingly difficult and you cannot find anything that looks like a genuine optimizing routine, but, secondly, I have found that people do not trust this anyway. If you have got something that does optimize you can do the calculations. Open pits are quite a good example of this. But nobody will buy your final open pit, they will have to go back and work all these different alternatives out for themselves otherwise they do not really have any confidence in the final answer you came up with.

Well, all I would like to do now in winding up, is to make one or two general observations about the computer applications area. I am afraid they are a little bit gloomy, but I think what we should try to do is to learn from our experience over the last 10 years and then use this as a foundation for our activities in the future. Firstly, I think if we look back over the last 10 years we have to admit that the problems that we have encountered have been consistently far larger than we expected. I know of very few exceptions to this. Although you get people who write papers, and so on, and say this is a simple little program and they did in in two days and so forth, in practice any kind of system, which is going to be of use in an organisation, seems invariably to involve people in much more time and effort than originally expected. I think I can say if we go back to where we were about 10 years ago and have a look at where we are now, to be perfectly honest, we must be disappointed. Although we can be very pleased with a lot of what we have done, I think we hoped to get much further in 10 years.

Another thing we have done has been to proliferate systems and we have squandered resources on unnecessary duplications. Now it is a characteristic, of course, that everybody thinks that he can do something better than you can. But this is a characteristic I have found that applies particularly in the computer area. People will always re-invent their own systems for some reason or other and will assume that other people's systems cannot possibly be good enough; just think of the number of payroll systems or multiple regression systems there have been. At one stage everyone was writing his own multiple regression program.

Also, we spent large sums of money which it would be difficult to justify in commercial terms. I think this observation is fairly well accepted now. If you go back to companies' experience over the last 10 years and try to get honest and genuine assessments out of them it is very difficult indeed to find applications which are easily justified commercially. You find a lot of people who will say that they have done tremendous things, but it is difficult to get genuine facts, such as 'this has been a successful commercial application in the sense of', for example, '15 per cent d.c.f. return' or whatever is the appropriate measure. Surely, we are trying to do something commercially useful.

Another point I would like to make is that I think we have failed to make the impact on management that we should have made. This is a very significant observation. Although we have seen a lot of computer developments, I think a lot of it has been in the research area and a lot of it has been in the commercial applications area. There is some doubt about the extent that we have got beyond these areas of application and have influenced the way in which people take decisions in relation to the way in which they run their companies. I feel we have not penetrated this area to the degree that we should have.

I think all this sounds a bit gloomy so I will finish up by saying, nonetheless, hopefully we have learnt a lot and achieved at least a solid foundation for the future.

Now, since this is a keynote talk, I must finish with a keynote, but I find I do not have one, I have two.

Number one is marketing. This is going back to the observations I have just made. The value of what we do as a group working on computers and computer systems is assessed by our market. This is an elementary observation from a marketing point of view and I think the market for whom we are working is management in general. We have, therefore, got to be concerned with, and we have got to concentrate on, the production of systems of relevance to management's problems.

The second note I wanted to sound is one of professionalism. I think we have been in this business long enough now, 10 or 15 years, to have acquired a certain professionalism in the line in which we operate. I would like to say let us, therefore, be realistic in our claims and honest in our assessment of the time and resources which are necessary to achieve this. Thank you very much.