WESTERN AUSTRALIAN
TECHNOLOGY & INDUSTRY ADVISORY COUNCIL

Western Australia's Minerals and Energy Expertise: How can it be Optimised?

Defining the Issues: A Background Paper

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EXECUTIVE SUMMARY

This background paper is intended to stimulate an informed debate on the topic of the expertise available to the Western Australian Minerals and Energy Industry. There are certainly conclusions to be drawn, but such is the diversity that lies hidden behind the seemingly monolithic term ‘minerals and energy industry’ that the Western Australian Technology and Industry Advisory Council (TIAC) would prefer that they emerge in the context of a broad community understanding of this complex whole.

For this reason TIAC decided that this background paper should refrain from setting forth conclusions and recommendations. In the absence of conclusions this 'executive summary’ is better described as a guide to the paper.

This paper is unashamedly discursive in style, setting out to capture, with very broad brush-strokes, something of the views, opinions, and positions that have emerged in listening to a significant number of key players in the industry and its suppliers of expertise. The level of detail reflects the balance between opposing recommendations to expand certain sections ‘because they are really important’, and to condense others ‘because they are common knowledge’. The reality is that there is no consensus on what is important and what is mundane.

Thus, whilst some may be familiar with all the field covered here, most readers will have knowledge of some parts but not others. One way of approaching it is therefore to read first those sections dealing with familiar parts of the scene. This will give a feel for the level of detail in the coverage. This understanding will allow the exercise of a sense of proportion in tackling topics that are relatively new to the reader.

The following reproduces the introductory section of each of this background paper’s three main chapters. The first of these concerns the minerals and energy industry itself. The second describes the research scene. The third deals with education and training.

The minerals and energy industry, its technical needs and suppliers

This chapter starts with a ‘thumbnail sketch’ of the minerals and energy industry, and goes on in its eight sections to consider what this means for those who would be suppliers of technology to it. The examples are biased towards the supply of research, but the discussion has wider application within the field of technology.

> **The industry is fundamentally extractive. It exploits non-renewable resources, and once the extraction has occurred the situation is forever altered. The industry can only return when developments in technology and depletion of richer resources elsewhere make it economic to go back and treat deposits, or waste dumps, that were previously below the economical cut-off grade. It therefore has a continuing need for access to new resources.**

1. **The first section sets the scene by describing its relationships with a State in which it operates, as part of a global economy. It is important to understand at once that the needs and priorities of the Industry and the State will not always coincide.**

2. **The second section makes the point that industry is more complex, and possibly more interesting, than the convenient description 'minerals and energy' might suggest. It goes on to consider several ways of breaking down the industry into categories to show how the technology needs of different parts may differ significantly.**

3. **This leads into the third section, which lays out some scenarios for would-be providers of technology to the industry. There are some significant changes taking place and these provide opportunities, but only for the World-class suppliers.**

4. **Despite the intention in this paper to refrain from drawing conclusions, the fourth section contains the following key paragraph:**

   > **The overwhelming conclusion is that producers in the globally oriented minerals and energy industry are driven to using no less than World-class expertise to tackle anything that has a serious impact on their business. This makes it tough for a new technology supplier to get started. What is needed is a track record of delivering value to the industry.**

   The challenge for suppliers in getting a track record of providing value to the industry is the main theme taken up in this section.

5. **One of the ideas that emerge from the discussion is that of 'World-class Centres of Excellence'. For a rather nebulous concept there is surprisingly wide agreement in the industry on which research suppliers have attained this status; the fifth section comes to grips with what it is, and how to get it.**

6. **The sixth section considers the benefits of attracting a potential centre of excellence to a State. It goes on to draw some lessons from the example of a decision of where to locate a private-industry corporate research centre.**

7. **The seventh section follows directly from these considerations by discussing the forthcoming establishment of a CSIRO National Centre for Minerals and Petroleum Resources Research in Perth.**

8. **But what of local expertise that is not quite World-class? Surely the local industry is prepared to 'give it a go'. The eighth and final section takes a hard-nosed look at the industry's support for local research expertise. The answer to the question is "yes, it will help - a bit". It concludes by drawing attention to the role, potentially an increasingly important one, of professional institutions and technical societies in developing local expertise.**

> **It is surely significant that in none of the discussions did there arise any suggestion that the Western Australian industry was being seriously held back by a lack of research providers. There may be gaps in local capability to supply some needs, but the industry's global competitive focus drives it seek such resources wherever it can get them.**

The external research scene

Much of the discussion about making best use of the State's expertise in applying science and technology in the minerals and energy industry concerns the State's external research capability. The internal research capability within the firms in the industry is a separate matter on which the companies make their own judgments. However, even businesses with their own internal facilities make use of external providers. Their capabilities thus have a potential impact on the success of the industry. It also has a vital bearing on the potential for the State to develop its research industry through attracting research work from a wider client base.

> **The observation made in the introduction to the previous chapter, that the industry does not appear to be markedly held back by the absence of research capability in this State, suggests rather that the presence of the industry represents a market opportunity that local researchers might pursue. It should do this while the industry is strong, bearing in mind that it is subject to cycles, and being extractive, its continued strength and even its presence cannot be taken for granted.**

The picture of the external research scene is displayed here in seven sections. While the previous chapter dealt with research excellence, the dominant theme in this chapter is money.

1. **The chapter starts by giving a feel for how the industry makes use of research, and estimating how much it spends on research performed by external providers. It attempts to bring some reality to expectations that researchers and government funders may harbour concerning size of the industrial market for external research. It suggests that, overall, the amount of money available for external research providers may be around 0.2% of the value of the industry's production, and hence its conclusion is that:**

> **The size of the 'pie' is considerable, but it is not unlimited.**

2. The second section introduces some of players in the external research game, and identifies their major sources of income. It also describes the role of two important research brokers.

> It is surely quite significant that researchers are described as 'seeking funding' from industry. The alternative of 'seeking to solve industry's problems' is rarely if ever heard.

3. The third section discusses the nature of the relationship between industry and the external researchers. There are frequent and recurring misunderstandings, which need to be clarified. One of these concerns the value of money to the different parties to a research contract, and this is explored briefly.

4. The next section explores the process by which a university researcher might grow an embryonic capability into an established centre. The Julius Kruttschnitt Mineral Research Centre within the University of Queensland is used as a model because of its long track record of continuing growth and the frequency with which it is mentioned as an example by people within the minerals industry.

5. This leads to the fifth section dealing with Cooperative Research Centres (CRCs). Getting research funding is always a challenge, and the real test of viability is whether a centre can sustain its funding base.

6. Some of the ways researchers go about getting the funded work that they need to maintain viability are covered briefly in the sixth section.

7. The chapter concludes with a short section speculating on the future of the traditional PhD system.

The current education and training system

This chapter deals with the suppliers of trained people into the minerals and energy industry. Much of the recent discussion on this topic has centred on the university system, so this sector receives most attention. However, this chapter also shines some light on what is happening in the Technical and Further Education (TAFE) arena.

1. The chapter starts with an overview of the State's universities and their funding. These financial realities have tended to discourage the universities

from adopting some of the ideas for change that the industry has suggested. This is taken up in the next two sections.

2. **Thus the second section expands on the industry view of the university system. This draws on the Discussion Paper published by the Education Taskforce of the Chamber of Minerals and Energy of Western Australia in 1996. It does not, however, accept everything in this paper at face value.**

3. **The third section examines the view from the other side: how those in the universities see their role. This reveals an important cause of misunderstanding. The industry thinks that it is the customer for the universities' services. However, as far as the universities are concerned the student, not the industry, is the customer. The Chamber's vision of a rationalised system runs up agaist the reality that:**

> **... the present regime of funding tertiary education works by competition for student enrolments. Under such conditions no institution is inclined voluntarily to withdraw from offering courses that students might find attractive**

The section goes on to say a little about how the different universities are going about the business of attracting students.

4. **Following the publication of the Chamber's discussion paper a succession of events has led to the establishment of a committee to progress the formation of the 'Western Node' of a proposed National Centre of Excellence in Teaching and Research in Minerals and Petroleum. The fourth section describes current moves in the Western Australian university sector in relation to this development.**

5. **Many of the problems that occur between the industry and the education sector are tied up in the dynamics of recruitment. It takes a considerable time to train someone for the industry, but the industry is notoriously cyclic and graduate supply and demand are frequently out of step. The section goes on to consider the consequences and possible remedies**

6. **The TAFE sector is covered in the sixth section. This sector seems poorly understood, and may be under-valued, by the minerals and energy industry, possibly because the system is quite complicated and in a process of change that has not yet entirely stabilised. The implications of the changes to funding and the move to competency-based training are only now beginning to become apparent to industry, and concerns are emerging about training at supervisory level.**

7. **The seventh section refers to prospects for growing the education industry.**

8. **The final section touches briefly on continuing professional development and distance education.**

1 INTRODUCTION

The Western Australian Technology and Industry Advisory Council (TIAC) is interested in the optimal use of Western Australia's mineral and energy expertise (the usage of the term minerals and energy industry is explained in the Glossary, Appendix E). This interest follows from its own summary of the present situation:

> *The majority of Western Australia's export earnings come from the mineral and energy industry. The continued fall in real returns for mineral and energy product puts continuing pressure on Western Australian industry to be competitive. Companies need to increase productivity by four to eight percent annually to remain on the cost curve [Appendix E]. These gains cannot be achieved with the present technology alone, in fact, in some areas of these industries competitors are better resourced for research and technology. The industry's future will rely on a well educated workforce, a stronger knowledge base, the development and application of sophisticated technology and technology transfer systems.*
>
> *Individuals and companies prefer not to be the sole investors in fundamental research where risks on return are high and investment time frames are long. Government has a valid role in supporting and encouraging that research and promoting strategic direction to ensure research is appropriately focused on the long term needs of the industry.*

It is TIAC's intention to undertake a number of studies that will enable it to advise the Government on policy to support the minerals and energy industries in their quest to remain internationally competitive.

This goal is closely aligned to recent State Government initiatives relating to technology in the minerals and energy industry. Thus, in April 1997 the Government of Western Australia adopted a Science and Technology Policy which incorporated a number of specific objectives and strategies defining the Government's role in promoting, *inter alia*, *"… new technology-based businesses, engineering solutions for environmental problems, increased value-adding to our agricultural and mineral resources …"*

In particular, the Government's role includes creating *"a vision for the development of science and technology in the State, supplying necessary public infrastructure, and supporting appropriate industry and community initiatives."* **Its strategies in this area are described under a set of objectives, which include Objectives 13, 17 and 22, which, respectively, are to:**

"Increase the level of expenditure on research and development in the minerals sector"

"Encourage increased investment by industry in research and development in Western Australia"

"Assist the establishment of internationally competitive science and technology infrastructure within the State's universities, the vocational education and training sector, and other research sectors"

The Technology and Industry Advisory Council considered that it would be appropriate, before embarking on these policy development studies, to establish an overview of the minerals and energy research and development (R&D) sector in the State. The present study, commissioned by TIAC, is intended to provide a background against which key issues for policy advice may be considered.

1.1 STUDY OBJECTIVE

The formal objective of the study, as defined by TIAC, was:

> *"To identify the status and focus of current research and related relevant facts for the purpose of developing a vision for supporting research for the Western Australian Mineral and Energy Industry"*

This study has a broad scope that recognises the practical difficulties of trying to separate research from aspects of education. It extends to encompass relations between the industry and the tertiary education sector, both university and TAFE. The study took into account the Discussion Paper prepared by Tertiary Education Taskforce of the Chamber of Minerals and Energy of Western Australia and published in 1996.

In another direction, the boundary between research and the provision of technology services in general has not been drawn too precisely, as lessons and experiences can usefully be transferred from one sector to the other.

The State Government has a long record of support for minerals and energy research through MERIWA (the Minerals and Energy Research Institute of Western Australia). Two more recent State Government initiatives also formed part of the context for the study. One of these is aimed at establishing a Centre of Excellence in Teaching and Research in Minerals and Petroleum. The other is an arrangement with CSIRO to locate a National Centre for Petroleum and Mineral Resources Research in Perth.

In developing the scope the consultant was asked to concentrate on gaining an appreciation of the view from industry, and the main method of achieving this was by interview. The industry views were supplemented by interviews with people in the research, education and government sectors. The number of people interviewed (more than 50, with varied roles in the minerals and energy field, Appendix C) was considered sufficient to identify both the domains of broad agreement and the areas where opinions differ significantly.

The purpose was not to catalogue what capabilities exist in Western Australia, not to list those that the industry has had to source from outside the State. Rather, it has been to identify major driving forces leading to the use of technology (defined in Appendix E) and the development of a technology capability.

This is a subject in which there are very few official views; beyond a bare outline of facts almost everything learnt during the study involves a degree of interpretation or opinion. Thus there is simply no way of ensuring that every position has been heard and correctly interpreted. Comment is therefore invited, particularly if it is considered that an important viewpoint or interpretation has been overlooked or misrepresented.

The Terms of Reference for the complete study are reproduced in Appendix A. The outcome to date, reported here, has been a description of the 'state of play' in three critical areas. These are covered in three separate chapters. The first of these concerns the minerals and energy industry itself. The second describes the research scene. The third deals with education and training.

These three chapters form the main body of this background paper. They are an attempt to capture, with very broad brush-strokes, something of the views, opinions, and positions that emerged in the interviews. They provide the background from which the key issues are to be extracted.

This format has been adopted in order to cut through the inherent complexity. The areas are, however, inextricably interlinked, and appreciation of each chapter is strengthened by a knowledge of the fields covered in the other two, which serve to place it in context.

1.2 The national context

This paper has its focus on the Western Australian scene. However, it is written at a time of considerable ferment in the development of national policy on industry and on science and technology. Currently several separate but related reports have been presented for consideration by the Federal Government. These reports include:

- The Mortimer Report "Going for growth" (June 1997)
- The Goldsworthy Report "The global information economy, the way ahead" (August 1997)
- The Chief Scientist's (Stocker) Report "Priority matters" (June 1997)
- The Metal Trades Industry Association (MTIA) Report "Make or break: 7 steps to make Australia rich again" (August 1997)
- The Australian Academy of Technological Sciences and Engineering (ASTEC) Reports "The competitiveness of Australian Industry, Report Number 3: The Minerals Industry" (July 1997)

In addition, the West Report on Higher Education is currently in preparation, and within the industry, the Minerals Council of Australia will soon release its report on meeting the educational needs of the minerals sector.

The decisions the Federal Government takes on these reports are likely to have far-reaching effects on the minerals and energy industry and on the use of technological expertise within it. It is therefore significant that the reports published to date differ profoundly in their recommendations on at least three areas that strongly impact the field surveyed in this background paper:

R&D incentives

- **Cooperative Research Centres**

- **CSIRO**

In some cases recommendations on these are so diametrically opposed that the reviewers seem to be coming from quite different standpoints in their judgements. This can only mean that the different reviewers hold very different expectations of what these critical factors in Australian technology are intended to achieve.

This is a pervasive theme, and such unacknowledged differences in the expectations held by different parties are also evident throughout the present background paper. Arguably one of the most immediately valuable outcomes of these reports will be in getting such differences in expectations out into the open where they can be debated.

2 THE MINERALS AND ENERGY INDUSTRY, ITS TECHNICAL NEEDS AND SUPPLIERS

This chapter starts with a 'thumbnail sketch' of the minerals and energy industry, and goes on in its eight sections to consider what this means for those who would be suppliers of technology to it. The examples are biased towards the supply of research, but the discussion has wider application within the field of technology.

1. **The first section sets the scene by describing its relationships with a State in which it operates, as part of a global economy. It is important to understand at once that the needs and priorities of the Industry and the State will not always coincide.**

> **The industry is fundamentally extractive. It exploits non-renewable resources, and once the extraction has occurred the situation is forever altered. The industry can only return when developments in technology and depletion of richer resources elsewhere make it economic to go back and treat deposits, or waste dumps, that were previously below the economical cut-off grade. It therefore has a continuing need for access to new resources.**

2. **The second section makes the point that industry is more complex, and possibly more interesting, than the convenient description 'minerals and energy' might suggest. It goes on to consider several ways of breaking down the industry into categories to show how the technology needs of different parts may differ significantly.**

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> started. What is needed is a track record of delivering value to the industry.

The challenge for suppliers in getting a track record of providing value to the industry is the main theme taken up in this section.

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2.1 The Minerals and Energy Industry and its relations with the State

The factors that govern the continued growth of a minerals and energy industry within a State can be grouped around four major concerns:

- a market - a mineral deposit is not a resource unless there is a buyer for the product

- prospectivity - there has to be a hope of finding a resource

- **access to the resource - immediate and long term**
- **costs of extraction and processing - and (with environmental regulation) exit**

A state or nation cannot sustain a minerals and energy industry without a natural endowment of resources that are in demand. All of the other factors that can affect the attractiveness of a country to businesses in this industry are subsidiary to this. However, deficiencies in any one these can preclude, limit, or result in the run-down of a minerals and energy industry.

2.1.1 Setting the scene - a sketch of the industry

The complex picture of the relationship between the industry and government that arises from this exploration can best be grasped through a 'thumbnail' sketch (intentionally something of a caricature) of the industry.

The industry is fundamentally extractive. It exploits non-renewable resources, and once the extraction has occurred the situation is forever altered. The industry can only return when developments in technology and depletion of richer resources elsewhere make it economic to go back and treat deposits, or waste dumps, that were previously below the economical cut-off grade (Appendix E). It therefore has a continuing need for access to new resources.

The industry is globally oriented. Its desire is to have free access to the richest mineral and petroleum resources available anywhere in the world, while having to pay the lowest possible royalties and taxes. Existing infrastructure helps with the cost side of operations, but if the resource is good enough it is prepared to go anywhere regardless of infrastructure. It will also go anywhere in the world for the expertise it needs to solve its problems.

The industry is very competitive, and companies within it are very sensitive to public expenditure that is felt to assist their competitors. More generally, the industry is unhappy with money collected from its activities and then spent by others (especially by governments) supposedly on the industry's behalf. It believes that the companies within it are the best judges of what they should spend money on. Furthermore, since it is a net contributor to the revenues of the states in which it operates, it can argue that virtually any spending by governments effectively includes a component of money collected from the industry.

That having been said, the industry is very conscious of the need to maintain a 'social license to operate' as part of the deal for continued access to resources.

The industry speaks collectively with greatest conviction when it argues against charges, and limitations on markets and access to resources. Other pronouncements tend to carry less weight because the industry is in reality anything but monolithic, so that 'when push comes to shove' individual companies are liable to break ranks *for their own interests. In reality the term industry is simply a shorthand term for a remarkably diverse collection of enterprises, with a wide range of different desires.*

That first paragraph is so defining, yet so often overlooked, that it is worth repeating

The industry is fundamentally extractive. It exploits non-renewable resources, and once the extraction has occurred the situation is forever altered. The industry can only return when developments in technology and depletion of richer resources elsewhere make it economic to go back and treat deposits, or waste dumps, that were previously below the economical cut-off grade. It therefore has a continuing need for access to new resources.

2.1.2 The influence of governments on the industry

Governments cannot substitute for Nature in providing deposits, they can however, influence all the other factors. For example, government policies can make a mineral *deposit* **inaccessible or uneconomic. In other words, they can affect its conversion into a** *resource***.**

Under certain circumstances governments can substitute for markets, however for most minerals, and under normal circumstances, they do not. The areas where governments always have a critical influence are in access and costs.

(a) Markets

Governments may decide to stockpile strategic materials they deem to be strategic. This happens most especially in times of war, when they may also subsidise normally uneconomic operations. An example of this is tungsten production in Australia. Governments can also exert marked effects on markets through, for example, export controls - the development of the Western Australian iron ore industry depended on the relaxation of export controls. Government influence can also be exercised through centralised or monopolistic purchasing arrangements. This can apply at international as well as national and state levels, most clearly exemplified by the fixing of the price of gold when it was the standard for exchange rates.

Where governments are active in the market changes in their policies can be quite disruptive. The release of Russian aluminium to the World market is one example. The sale of national gold stockpiles is another

Market manipulation is open to more than one player; it's not just a game for governments. Producers, buyer, and traders have been known to form cartels, or to attempt to corner markets. The OPEC (Organisation of Petroleum Exporting

Countries) arrangement of the early 1970s is one example. Diamonds provide another, and a more enduring one. Gold and diamonds, with limited industrial uses, are prime candidates for market manipulation of one form or another.

Minerals and energy businesses are part of a global market for products and capital, where money, technology and people, are highly mobile. Putting it bluntly, the interests of the companies and enterprises are not necessarily the same as those of the Nations, let alone States, within whose borders they may currently be operating.

(b) Access

Provided it is accessible, there is nothing like a good resource in making a mining or energy enterprise profitable. For example, Grasberg in West Irian, is rich enough to attract a mining operation despite the cost of having to operate above the snowline on the top of a mountain in an largely unexplored equatorial jungle, with limited pre-existing infrastructure, and even with a hostile element among the local population. In the petroleum industry, the need to develop new technologies, and new ways of working and living, have not prevented the exploitation of offshore resources in increasingly difficult locations.

Access depends on the legislative framework provided by the State, the authority of the State, and ultimately on the will of the people who make up the State. The closure of Panguna mine on Bougainville proves just how critical is the requirement for continued access.
Environmental concerns and safety are extremely important in this regard. Disposal of tailings has loomed large on Bougainville, has resulted in violence at Grasberg, and achieved notoriety for the industry at Ok Tedi. In offshore petroleum operations disposal of hot saline formation waters (that are extracted with the oil and gas) has less visible effects, but is raising concerns. Safety has already been elevated to a major preoccupation in offshore operations - the Piper Alpha disaster in the North Sea was a defining incident for this industry. In the mining industry, a record of fatalities and failures seems, up until now, to have been accepted with relative equanimity by the population at large. This cannot be counted on to continue.

In short, the minerals and energy industry needs to maintain its ‘social license to operate’, and the State has a role. The State, after all, may be more interested in maintaining a long-term minerals and energy industry within its boundaries than are some of the globally oriented companies that form the industry.

(c) Costs

The influences of governments on the costs incurred by the industry are discussed in the next section.

2.1.3 How governments affect costs

Costs of establishing and operating a minerals and energy venture are subject to varying degrees of State government influence. These include:

- **royalties, rents, levies, taxes and charges, facilitation payments and concessions**
- **energy, infrastructure, and water**
- **exchange rates and labour**
- **environmental**
- **interest on capital**

(a) Charges

Charges such as royalties and taxes are directly under the control of governments. The minerals and energy industry is generally, and on principle, against these. Levies on consumers of products of the industry, e.g., petrol taxes, cause the industry less concern as they follow the 'user-pays' principle. However, a major difficulty with such consumer levies is that they are hard to apply to exported products. In any case, the industry certainly argues against such levies when it is itself a major consumer, as with the diesel fuel rebate.

Governments can offer loans, and concessions on taxes and charges. The industry as a whole favours concessions that apply to the whole industry, and is collectively suspicious of targeted concessions that might make a particular marginal venture more viable. This is branded as 'picking winners', and the industry view is that Australian governments have a poor track record in this activity.

(b) Energy, infrastructure, and water

The influence of government on energy, infrastructure, and water costs can be to the benefit of the minerals and energy industry, or to its cost. The minerals and energy industry is a large user of energy, especially in further processing of its products, and policies that raise the cost of energy are generally seen by the industry as tantamount to taxes. However, the provision of infrastructure and water can be seen either positively or negatively.

The industry is very conscious of the net wealth that it generates for governments, and wishes to see government expenditure returning benefits to the industry. However, its position overall, reflecting its distaste for taxes and

charges in the first place, is that individual enterprises in the industry should have a say in how this is spent. Thus infrastructure that addresses a wide regional deficiency is more likely to be favoured than is more targeted development. At least, that will be the collective industry view. Individual companies within the industry are likely to be rather more favourably inclined towards developments that are targeted at their own particular needs.

The existence of human expertise is generally regarded by the industry as an infrastructure item. If it is lacking it can be provided at a cost, as the Grasberg example demonstrates.

The reason for singling out water as distinct from other infrastructure is to highlight the lack of good quality water as a particular issue for Western Australia. For example, the ability to use the carbon-in-pulp process with saline waters lies behind the revolution in gold production in Western Australia. Looking ahead, the demands for process water will have a major influence on the cost of further processing of mineral and petroleum products here.

(c) Exchange rates and labour costs

Moving down the scale of State Government influence, exchange rates and labour costs reflect broader, and mainly national rather than State, government policies. Policies on the use of immigrant or expatriate labour, and the training of locals to replace them, have both short term effects, and a longer term influence on the pool of infrastructure expertise available.

(d) Charges for environmental impacts

Environmental issues are reflected in costs as well as in the question of access, and now extend beyond the life of a particular project to include site rehabilitation. Moreover, environmental costs raise unresolved questions about differences between financial and environmental accounting. Proposals for carbon taxes, and commitments on greenhouse gases have huge potential to influence the future of the minerals and energy industry, but are moving beyond the control of single national governments. Energy exporting countries like Australia will be especially subject to conflicting pressures from the different trading and eco-political blocs.

(e) Interest rates

Interest rates on capital are set by global markets. The effect of State and Australian government policies on global minerals and energy companies is mainly manifest as exchange rate movements.

2.2 THE 'MINERALS AND ENERGY INDUSTRY' - NOT AS SIMPLE AS IT SOUNDS

It is common to speak of "the Western Australian Minerals and Energy industry" (Appendix E). This convenience in speech can lead us to make the mistake of believing that the industry is as monolithic as the phrase suggests. In fact, the term is no more than a short way of referring to a collection of very different sectors, and different enterprises within the sectors. These can all have quite distinct characteristics and needs.

There are some obvious ways the industry can be broken down into sub-groups, e.g., by product, or by geographical location. Company groups are often structured around such divisions. It clearly makes sense to talk of 'the gold industry', 'the oil industry', or 'the mining industry in the Pilbara'. However, there are other less familiar, but very useful ways of dissecting the industry. Each cross section has something to add towards building up a feel for the complex whole.

This section discusses some of the characteristics of 'the industry' that are revealed by the following various ways of segmenting the industry:

- Petroleum versus Mining
- Producers versus Suppliers

- Categorisation by place in end-product life cycle (Appendix E)
- Producers of commodity products versus tailored products

- Categorisation by place in venture life cycle

Each of these helps give a feel for what is important to the various companies in the industry, and how their needs differ. Each gives a separate insight into the remarkably distinct technology needs that companies may have. Businesses may have different needs from others producing the same product, and needs within a single firm will generally change over time. An appreciation of these differences should be helpful to anyone who would be a supplier of technology to the industry.

In particular, the last two categorisations (commodities versus tailored products, and place in the venture life cycle) together provide a very useful way of coming to terms with differing needs for expertise and technology.

2.2.1 Petroleum versus Mining

There is plenty of evidence of differences between the petroleum and the mining (both minerals and coal) industries (Appendix E). Whether or not these differences are fundamental, they do give quite a distinctly different flavour to the two parts of the Minerals and Energy Industry.

Even though the Chamber of Minerals and Energy of Western Australia has broadened its base (with its change of name from Chamber of Mines), it is still predominantly concerned with mining. It is also important to note that the Chamber, although it certainly numbers among its members the largest mining companies operating in the State, is not the only body that represents the industry. The Association of Mining and Exploration Companies sets out to speak for the generally smaller firms that comprise its membership.

Some suggest that the petroleum companies are still 'testing the water' to see if they have a useful role in the Chamber's expanded grouping. An alternative points out that the 'upstream' (see Appendix E) petroleum producers are already served through membership of the Australian Petroleum Production and Exploration Association (APPEA).

It has also been suggested that the Petroleum side is concerned that it might be 'tainted' by association with the Mining industry, which is seen to have a less happy recent record in safety and industrial disputation, and whose effects on the landscape are perhaps more visible. The two industries are, moreover, covered by different legislation.

The petroleum industry is also relatively new in Western Australia, and has turned for experience and leadership to long-established overseas parent companies. In contrast, Australia has a long record of leadership in mining and minerals processing innovation. There may also be a factor in the rapid and constant circulation of petroleum engineers and executives around the world - expatriates are a feature of the petroleum industry. This may produce a loyalty and association to the industry and its companies rather than a particular country. The mining industry is also global in outlook and movement, but not to the same extent. As another contrast, the top management of the petroleum companies remains predominantly drawn from engineering ranks, whilst in the global mining companies engineers no longer hold such dominance.

The petroleum industry employs far fewer people per unit value of production, with about 6 000 in total in Western Australia as opposed to about 40 000 for mining. It also appears that the workforce in petroleum is somewhat more stable, and its training needs, especially for offshore work and well drilling, are more specific and handled within the industry rather than by other providers.

On the exploration side, there is a real difference simply because petroleum fields and mineral deposits are found in different geological structures. Of course, there are also great differences in the structures where different minerals are found. However, the dominance of seismic exploration for petroleum is certainly such a characteristic that the discipline of geophysics divides effectively into petroleum geophysics and mineral geophysics.

The last couple of decades witnessed a substantial move by petroleum companies into the coal mining industry, only to be followed by a major divestment. Similarly, mining companies that entered the oil business have, with the notable exception of BHP, largely withdrawn from it. This is suggestive of a significant difference, but perhaps not too much should be made of it. Large and successful mining groups have not always found it easy to transfer their successful track records to operations with one mineral commodity to another with which they have had little prior experience.

2.2.2 Producers versus Suppliers

In this cut through the industry, the word 'producers' refers to those who have the authority to exploit a resource, whether or not they actually conduct the operation. 'Suppliers' refers to those other companies which provide services and equipment to the producers, but which do not have the rights of exploitation. Such services may include the extractive operations themselves, as in contract mining. By extension, this use of the term producer covers the holders of rights to explore, and supplier includes those who do the exploration.

Many activities that could be carried out by suppliers may actually be carried out within producer companies. The stipulation that suppliers are companies that don't have the right to exploit the resource recognises that this right has a dominant effect on nature of the business. The following table lists some major differences in the situations and behaviours observed between the two.

	Producers	Suppliers
Underlying limits on profitability	Quality of mineral or energy deposit Financial engineering of project	Know how Uniqueness of, and demand for, products or service
Competition	Set by position on cost curve	Set by diffusion of know-how
Margins	Can stay high for a long time	Hard to maintain for long
Way value is gained from technology	Using the technology to increase efficiency of operation, or value of resource	Increasing sales of improved product or service

Scope for application of know-how and technology	Limited to number of resources leased or owned	Many potential customers, established or new
Key skills	Resource evaluation	Responding to producers' needs
Major threats	Entry of lower cost competitors (especially those with better resources) Substitution of other products in market	Undercutting by competitors (i.e., from loss of uniqueness) International competition and use of offshore expertise

2.2.3 Categorisation by place in end-product life cycle

The 'downstream' industries (see Appendix E) that use the output of the minerals and energy industries as their feedstock make products that have their own life cycles. For example, aluminium was once an embryonic product more valuable than gold. Now many metals have passed beyond the stage of maturity; the intensity of their use, per head of population, is in decline in the developed part of the World. The fact of varying patterns of use over time has a particular impact on the minerals and energy industries through the sorts of sales contracts that buyers prefer.

Markets will tend towards spot market trading if the end-users of the minerals and energy industry's products find they can substitute freely in a well-supplied market. Markets will move towards contracts when the economies that result from standardised feedstock become too large to ignore. End-user companies in mature markets typically compete on the basis of efficiency - novelty has long since passed as an attraction. This drives a move towards longer-term contracts. For example, iron ore is presently sold by long-term contract because blast furnace operators can obtain highest efficiencies by using constant blends of ore feed. In contrast, Electric Arc Furnace (EAF) steelmaking can use a wide range of metallic iron feed, as a consequence steel scrap (an 'honorary' mineral product) is a traded commodity subject to great volatility. However, as the EAF continues to become more important as a source of steel, direct reduced iron (DRI) is being increasingly produced from ore as a feedstock. The market for DRI will therefore be pulled in two opposing directions. Competition with steel scrap will move it towards a traded commodity. At the same time a growing EAF industry will no longer be able to afford the vagaries of the scrap market, and this will drive towards long-term DRI contracts.

At the same time, there will always be money to be made on spot sales, so as a product becomes mature a two-tier industry evolves. Major players will prefer contracts to protect their larger capital investments; smaller players will make money around the edges.

This leads to further classification on the basis of the nature of the mineral product.

2.2.4 Commodity products versus tailored products

According to this split, one group of producers in the minerals and energy industry consists of those whose products are tailored to particular customer needs through long-term contracts. The others turn out commodity products sold on the spot market. In general both will coexist, even for a single mineral product.

(a) Spot markets and contracts

Some spot-market sales takes place for almost every commodity. Nevertheless, it is clear enough that some minerals and energy products are predominantly sold by long term contract, and others are sold and traded as physical stock or futures. Gold can be sold freely; indeed, forward selling a vital part of most gold mining companies business. In contrast, obtaining a contract for, say, iron ore, coal, or alumina sales is a major, even make-or-break, undertaking.

As already mentioned the rationale for this method of classification lies in the ability of buyers to handle inputs of varying quality and quantity from a diversity of sources. The most obvious manifestation is in the relative importance of trading or of longer-term contracts. For example, smelting base metal concentrates on a toll smelting system (Appendix E) allows a spot trade in concentrates. Contracts come to the fore when there is less flexibility, either because continuity in supply is essential, or because processes using the materials are specifically tuned to a limited range of feedstock. Coal contracts for electricity generation are an example of the first of these, and alumina contracts for aluminium smelting illustrate the second.

(b) Value adding

There is a good reason why there is a more important market for alumina rather than for bauxite (the ore from which alumina is extracted). Bauxite ore is cheap and common, but highly variable in composition and its behaviour during processing. In contrast, alumina is a much more consistent product, and is already partway down the production process that leads to aluminium. Producers of aluminium metal consider it good value to have someone else (often, but not

necessarily, another division of the one corporation) convert the bauxite into alumina. Making alumina is a value-adding process. In contrast, high-grade iron ore (for example) can be sold with minimal value added; continuity of supply of a consistent product is often the main aspect of the added value.

Low-grade deposits of mineral or petroleum that no one wants to buy in their raw form demand value-adding processing and so there is no call for a spot market in them to develop. However, companies are not inclined to undertake expensive upgrading without a firm contract. The division between products aimed at spot markets and those sold by contracts thus often reflects the degree of 'value-adding' that takes place before sale. Nickel is an interesting exception; the ores require extensive processing to make a saleable product. However, there are few products in which nickel is the major component, and other elements can be substituted for it in many cases. It is therefore a high value-added product, but one in which there is a considerable and volatile trade.

Deposits of minerals that people are prepared to buy in raw form, oil for example, give the producer a choice of whether to engage in further processing before sale. However, value-adding to the commodity may not necessarily be 'profit adding' to the company. Thus, the interests of shareholder wealth may be better served 'digging it up and shipping it out' than by further processing. This, however, runs into conflict with the interests of community wealth which can flow from greater job creation and the multiplier effects of local downstream operations.

(c) Role of technology

Classification on the basis of commodity and tailored products throws up some similarities that are not immediately obvious. For example, in this respect oil (on-shore) has similarities to gold, and the 'wildcatter' has parallels with the independent gold Prospector. On the tailored product side, producers of gas (LNG) are seen to have similarities to producers of alumina.

With LNG and alumina the downstream demand for consistency has meant that considerable processing takes place before sale. The capital cost of entry is therefore high and technology tends to be proprietary. Even when alliances and joint ventures are used to ease the burden and share the risk, the technology in both these industries tends to be held by one of partners.

Iron ore provides a somewhat different example. Here value adding is achieved by an averaging process. Unsaleable lower grade ore is mixed with ore, which is of higher grade than the overall contract requirement. The blending process simultaneously achieves the upgrading and ensures a consistent product. This is rather simple compared to what is done with alumina or LNG, but nevertheless the most successful producers have based their activities around very large capital investments. Their technology is centred on managing and scheduling multiple inputs and operations to maximise the value of the total resource.

Operators who are prepared to mine only the higher-grade deposit and consign the lower grade material to waste can choose a different approach. This is what people refer to disparagingly as 'digging it up and shipping it out'; it may make sense under particular circumstances.

Both oil and gold provide a vivid contrast. With these commodities the existence of a spot market means selling the product is not a dominant problem, and the focus is on securing the rights to the resource, rather than on the technology of production.
This means that for deposits of a standard type there is a well-developed service industry ready to assist with operational aspects from exploration, financial services, project management and construction, through to extraction and sales. Entry costs are consequently relatively low, competition for provision of services is high, and technology circulates quickly.

Where technology may come to the fore is in converting previously uneconomic deposits into resources. For example, some biological oxidation leaching processes for gold ores have remained proprietary for extended periods. On the other hand, the revolutionary change to the gold industry brought by carbon-in-pulp technology came as a result of a conjunction of several technologies developed over many years, and spread rapidly throughout the industry.

The following table illustrates some of the differences made apparent by this dissection.

	Tailored products	Commodity products
Examples of products (dominant forms indicated, however the classes are not exclusive)	Iron ore Alumina Coal Liquefied Natural Gas (LNG) etc.	Gold Oil Base metals Nickel Scrap steel etc.
Sales	Contract	Spot market
Entry	Difficult	Easier
Business Focus	Marketing	Securing resources
Operational focus	Efficiency	Opportunism
Main way value is gained from Technology	Meeting contract grades and production	Exploration and evaluation

Spread of technology	Proprietary	Rapid diffusion
Suppliers	Fewer support services available	Wide range of supporting services available
Industry characteristics	Fewer players	More players
Prices	More stable	More volatile
Capital cost	Higher	Lower

2.2.5 Categorisation by place in venture life cycle

The minerals and energy industry is extractive and therefore any venture within it has limited life. A firm within the industry may have a long life, but only by a continued succession of the development of such limited-life ventures.

This leads to identifying three of the significant phases in the life of a venture: exploration, 'planning', and operation. As shown in the next table, the term planning is used to encompass several technologies. The table also shows that each of these phases has its own characteristics.

	Exploration	Planning	Operation
Technology and expertise	Knowing where to look Finding deposits that are there	Resource evaluation, which integrates: Process and flowsheet design Mine planning Marketing Financial engineering	Operational management Maintenance Capital utilisation
Capital	Low (treated as an expense)	Low (treated as an expense)	Highest (may be off-loaded to contractors)

Risk	**Very high**	**High**	**Lowest**
Way value is achieved	**Discovering potential resource**	**Maximising potential of resource**	**Minimising cost**
Perceived cost of delays	**Low (unless cost actually being incurred)**	**Low (unless cost actually being incurred)**	**Highest: capital not being used penalties may be incurred**

This split suggests the centrality of the area of 'planning' in a company that plans to be in the minerals and energy in the long term. This where its 'core competence' lies. This is where the ultimate value of the resource is determined, along with the price that can be paid to acquire the rights, and the costs at which the operation must run.

A mining group may conduct its own exploration, and may operate its own mines. However, even when this is the case, the hearts and minds of its top executives are most likely to be excited by evaluating new ventures.

This governs what can be out-sourced. Operations may be contracted out, especially for the producer of traded commodity. Companies may prefer to buy into discoveries made by others, especially for products tailored for longer-term contracts. The components that go into evaluation - process and flowsheet design, mine planning, and marketing - might also be contracted out. But it is hard to imagine how a producer company could contract out its capability for integrated resource evaluation capacity and remain viable. This is at the heart of its ability to add value to the deposit by turning it into a resource.

2.3 SCENARIOS FOR PROVIDERS OF TECHNOLOGY TO THE INDUSTRY

The analysis of the industry in terms of place in the venture life cycle (Section 2.2.5) leads to some conclusions concerning the importance of technology to producer companies. If operating producers of contracted tailored products run into technical difficulties they will pay whatever it takes, and go wherever they must to get quick solutions. The same goes for the producers of traded commodities in times when the market is up, and it applies to all producers who are in the planning stage, especially process and flowsheet design.

This has implications for those who would provide technology to the industry. Thus, there is a good outlook for providers of quick solutions to industry's problems. However, the forecast for researchers and technology developers is clouded.

2.3.1 Changing perceptions of the value of technology

Superimposed on these venture life-cycle considerations, there are times when companies in the minerals and energy industry turn to technology, and times when interest in technology wanes. The early days of AMIRA (the Australian Mineral Industry Research Association) in the 1960s were a time when the Australian minerals industry had a great deal of faith in technology and was willing to fund long-term research on a collaborative basis. Times have changed.

The first change has seen technology regarded as a competitive advantage, with the result that collaboration is harder to justify and shifts to non-competitive areas like environmental compliance. There is now a widespread sense that a second change is occurring. In this shift the value of the now-proprietary research-based improvements in technology is being questioned as to its worth in relation to the cost it takes to make them. The general (not universal) feeling in the industry seems to be that the path to greater productivity is by incremental improvement through benchmarking and being a 'fast follower'.

Whether this is actually true, or as its critics claim, a consequence of inadequate accounting for the value of know-how (or 'intellectual capital'), remains to be seen. However, the perceptions seem to be there, along with a faith that the technology for the future is already available, possibly outside the industry, and can be bought when it is needed.

Furthermore, the reduction of the 150% taxation concession to 125% has come at a rather critical time. In financial terms, the net value of the concession for companies paying the full current corporate tax rate is about 9%, while the cost of compliance is put at around 5%. It simply isn't seen as being worth very much. While the 150% concession was in place it is said that even the non-technical senior management (often the majority) accepted the importance of technology development.

Without ascribing a direct cause and effect relationship, this combination of circumstances is said to have made it markedly harder to interest senior management in technology in Australia over the course of the last year. Thus Rio Tinto (formerly CRA) has recently made deep cuts to its corporate R&D facilities. BHP has reduced the number of staff in its Melbourne laboratory by about 60 over the last year. However, in the same period the number of staff in its Reno laboratory in the USA has increased by about 50.

The whole issue of research incentives is a topic of current debate, over which there are deep divisions of opinion, as the divergent recommendations of the Mortimer and Goldsworthy Reports demonstrate. Mortimer recommends a reduction in the tax deduction to 100%, but compensates with an innovation rebate. This is of course better for loss-making companies than the present system, and while it is potentially equivalent to a 139% deduction, it is most likely to be somewhat less attractive than the present situation for tax-paying companies. Goldsworthy is advocating a 200% tax deduction, but based on R&D salaries.

The narrowing of the tax concession to remove the concession on capital projects such as pilot plants is clearly a matter of concern in the industry. The particular risk is that if pilot plant work is done overseas the subsequent building of full-scale plant will be even more likely to be done outside Australia as well.

2.3.2 Who is responsible for the operating technology?

Essentially, there are two components to making money from a minerals or petroleum venture. One is the inherent quality of the resource: its grade, size, accessibility, etc. The other is the efficiency of the extractive and processing operations.

Competitive advantage in operations depends on the quality of the workforce, and the technology employed. As the industry relentlessly becomes more global, as technology diffuses, and as the cost differentials for equal units of labour productivity fall, it will be increasingly difficult to maintain competitive advantages in this phase of the venture.

Increasingly, quality of resource is seen to provide the best chance of maintaining a low position on the cost curve throughout the life of the venture. The result is an increasing tendency for producer companies to see their core business in the planning phase, especially resource evaluation and financial engineering, rather than in operations.

Indeed, there is already a widespread feeling amongst research providers that a reduction in technical people on operating sites and in head offices has directly mitigated against the ability to drive R&D from industry, and to receive and appropriate the outcomes of research. It also puts into question the calls made by company executives (see Section 4.2) for the education sector to provide more technical graduates.

Whereas the cost of operations may have formerly been buffered by the richness of the deposit, companies are now more inclined to set tough cost-per-tonne targets on their operations independent of the overall profit. This shift in thinking relegates operations to cost centre, rather than a profit centre within

the business, and arguably to a less-well-regarded status within it. From there it is a small step to out-source operations to contractors. Either way, the question is then: who will be responsible for improving the technology of operating?

According to this analysis the profits of the producer companies are largely determined by the quality of the resource. However this has side-effects.

- **If the company conducts its own operations, and if its resources are good enough, it will be able to fund research into operating technology, but may not see operations as an important contributor to profits. On the other hand, if the company is struggling, and must rely on efficient operations to make up for poorer resource it will have less to spend on the improvements in technology that it needs to maintain profitability**

- **If the operations are contracted out, another snag is exposed. In this case the contractors' margins are based on their own skills and efficiency. Furthermore they do not stand to gain much from the benefits to the producers that flow from improvements in the operations; their profits are divorced from the profitability of the resource on which they are working. Their route to increased profit is through competitive advantage in efficiency over other contractors. In a highly competitive environment they are unlikely to have much money to spend on research.**

Either way, whether or not operations are contracted out, according to this scenario there is likely to be less funding available for research into operational improvements.

The offshore petroleum industry may provide some indications for the future of the industry. In this instance there do not appear to be fundamental differences which would insulate the minerals industry from the pattern which is already in place in petroleum where alliances, join ventures, and consortia come together to spread the risk and cost of development. This produces the intriguing situation of companies being participants in different and competing ventures. Minimising leakage of technology between members of consortia becomes an issue, and the situation has been reached where there are established producer companies that possess very little operating know-how. The joint involvement of Rio Tinto and BHP in La Escondida in Chile is a case in point.

This leads to a somewhat contrary assessment to the one following the scenario outlined previously. This second scenario makes operating know-how a business trump card for those few producers who possess it; it is a point of leverage for entering joint ventures.

This may be better news for those who are concerned about the future of technology, but it is likely to bring little reward to external researchers and

technology providers. Such advantages will certainly be held as tightly as possible in-house, and development will most likely be done in corporate laboratories. Besides, if there are fewer companies with operating technology know-how, it is by no means certain that these few will feel a continuing pressure to improve through research. Their operations may well become more like those of contractors, unless they can negotiate arrangements that allow them to collect a greater share of the profits, inherent in the resource, in return for the risk and expenditure they incur in technological development.

Gaining commercial success from developing new technology for the minerals industry has never been easy, and it looks as if it will get even harder. Yet, at the same time there are technology-driven companies, for example, Schlumberger, and Halliburton, that have been very successful in supplying engineering and technical services to both the exploration and production sides the oil industry. It might be useful to explore further the differences between the minerals and petroleum industries in this sense.

2.4 GETTING A TRACK RECORD AS A TECHNOLOGY PROVIDER

The classification described in Section 2.2.5 divided ventures in accordance with three stages of exploitation of the deposit: exploration, planning, and operating. This gives a useful insight into what technology suppliers have to do to become established. Looking at the industry this way, and taking account of its global nature, leads to the conclusion that the demand in all three phases is increasingly for World-class technologies - the competitive nature of the industry demands nothing less.

Thus there is a real problem for potential suppliers in establishing a track record that puts them in that class. The keys to gaining a track record are the ability to deliver value and the opportunity to demonstrate this. Each phase of the venture has its own particular technology needs and opportunities to demonstrate value, and these are sketched in the next three sections.

2.4.1 The exploration phase of the venture

Success in exploration comes from:

- **knowing where to look**
- **finding a deposit when it is there**

The distinction between these is important. In the latter case, the problem is that the easier finds have already been made. This drives the development of better geophysical and geochemical search techniques. With regard to knowing

where to look, one path to opportunity has been through gaining early entry to areas that were previously off-limits, either by politics or restricted physical access. This still happens. Another way is through access to large-scale structural geology of a region - as is provided in Australia by State Geological surveys. A third way is through developing conceptual models of the genesis of deposits.
There may still be a place for armies of geologists in the field, and poring over seismic charts, but the costs of gaining competitive advantage in this way are enormous, and the prospects of success are decreasing. The critical factor is increasingly the quality of intellectual input, and this is what companies are increasingly having to pay for in exploration.

2.4.2 The planning phase of the venture

In the planning phase, process and flowsheet design can make or break a deposit. The potential value is essentially determined before the capital is spent. Furthermore, once it is spent it takes enormous effort and expenditure to change the course that has already been set. The cost of this phase is ‘chicken feed’ in comparison with its consequences. Indeed, two or more parallel investigations are commonly conducted. Only the best in techniques, methods, trials, and intellect will do.

There is simply no role for a second-rate process and flowsheet design outfit. Companies go to wherever in the world they believe they can find the appropriate expertise for dealing with their particular deposit. Furthermore, the degree of specialisation is such that no one centre can hope to be the best in the World in more than a couple of areas of expertise.

2.4.3 The operating phase of the venture

The analysis of earlier phases doesn’t look too promising for the more or less competent group that - fairly or not - is not felt to be at the leading edge. Neither does the situation in the operating phase afford much comfort to such groups.

Any setback to the planned production of a tailored product on long-term contract is potentially disastrous. The same goes for a commodity producer when the market is running hot. A company facing such a situation goes to whomever is thought to be able to provide the greatest certainty of a rapid solution to the problem. Money is hardly an object. Location is no concern at all. Timeliness and capability are everything.

Even so, disasters can still happen. Advice can prove to be wrong. The fact that technological risk cannot be eliminated only reinforces the point that the calls

are made to those whose track record justifies the perception that they are the best bets to fix the problems.

2.4.4 Getting a track record

The overwhelming conclusion is that producers in the globally oriented minerals and energy industry are driven to using no less than World-class expertise to tackle anything that has a serious impact on their business. This makes it tough for a new technology supplier to get started. What is needed is a track record of delivering value to the industry.

Lucky breaks can happen. An expertise in a field unrelated to Mining and Energy can occasionally prove to be just what is needed. This is, however, no basis for a strategy. Section 2.2.4 describes some characteristic differences between companies producing for the spot market, and those who depend on long-term contracts. Using this as a framework, three paths to gaining a track record follow:

- **competing successfully in a local service industry which supplies a competitive local industry producing traded commodities**
- **forming alliances with contracted producers**
- **demonstrating expertise in obtaining operational cost savings, by developing and selling:**
  - **expertise**
  - **cost-saving products**

An active local contracting industry is generally an advantage, and in particular, provides a market for developers of cost-saving products.

Taking a rather different line, there is also a niche, though potentially a large one, in providing services that are essential, but which are not regarded as vital factors in competitive advantage. These are typically compliance requirements, and environmental services are a good example.

2.4.5 Supplying a commodity industry

With all of these paths the easiest time to get started is when the targeted sector is progressing steadily, with some degree of comfort. When commodities are in a boom producers want their problems fixed fast, and are not inclined to take unnecessary risks. When the bottom has fallen out of the market they can't afford to experiment. With the commodity sector a good time is when prices of a traded commodity at a median level - off the boil, but not at the bottom of the trough. The urgency to seek solutions to production problems is less intense and

the need to get the best available help as quickly as possible is correspondingly reduced. Unfortunately, the cash flow to pay for solutions is also weaker. This leaves an opening for lesser-known technology providers to establish a track record, but under relatively tight cost constraints. This can give a local group an advantage over more distant, even though more highly regarded, competitors.

The other time when there is a chance of getting started is when desperation has struck, and nothing else has worked; the trade-off is that the supplier may have to bear some of the risk, probably in return for a share of the hoped-for rewards of success.

An active competitive local commodity-producing industry can be a hothouse for developing local technology providers. The gold industry in Western Australia is a case in point.

2.4.6 Lessons from the contracting industry

The special circumstances that have led to the growth of what is without question an absolutely World-class contracting industry based on gold mining should be understood. In particular, it should be understood just how contingent this development has been on a particular combination of circumstances.

The Western Australian gold deposits (technically called 'supergene' deposits) that are currently being worked are a product of the weathering of the landscape. This has produced a large number of smallish, but easily worked concentration of gold. They are well hidden in the weathered surface (the 'regolith'), but local developments in geochemistry and geophysics, combined with the availability of structural geological mapping undertaken by the State, have led to a successful record of discovery.

Two other factors were necessary for discoveries to become valuable economic resources. The first was the floating of the gold price - no one would have looked at them when the price was pegged at around $30 per ounce. The cost of extraction depends on the grade of a particular deposit, but generally a price of around US$200 to US$300 is needed to make them economic. The other necessary condition was the development of the carbon-in-pulp extraction process, which is capable of extracting gold using the saline underground water in the region.

The discoverers of a typical supergene gold deposit had on their hands a deposit that was too small to justify establishing an in-house mining capability. At the same time, the deposits were easily mined, and there were a good number of them. These were just the conditions where a contract mining industry could become established. Contracting now extends to just about every aspect of the gold exploration and mining business.

Now that it has been established it is probably capable of continued growth and survival. Already it is spreading into other industries, such as iron ore mining, where it is most unlikely that it could ever have started. However, it is well to remember that those special circumstances that allowed its birth have already passed; the supergene deposits are on the way to exhaustion in this State. There is no prospect in sight that anything similar will take its place. If the industry were to fail at this stage - and this could happen - it is most unlikely that it could be resurrected.

2.4.7 Partnership with a contracted producer of tailored products

The second route to a track record is through partnership with a long-term contract producer. As explained above, there are very strong pressures leading to the use of World-class expertise to solve problems, regardless of where it happens to be located. There are also two major disadvantages in doing this. The first is that it tends to be expensive (even if it is good value). The second is that the expertise to solve the problem may remain far away from the operation. If this distant expertise has to be invoked repeatedly, the cost will be similarly high each time. An alliance with a local technology supplier to develop specific skills in (non-proprietary) aspects of the operation can therefore be a useful investment.

Giving contracts for smaller and less urgent work can allow a local technology supplier to build up expertise in parts of the operation that cause occasional difficulties. The expectation is that such focussed expertise will pay off in future, possibly by averting major problems that would require more expensive interventions. The local supplier builds a track record, while the producer pays a more or less regular modest premium to build a buffer against major problems.

A potential down side for the supplier of this technology is that the expertise will not generally be available to the producer-partner's direct competitors. However, such is the nature of the business of making tailored products that there will generally be relatively few of these. The supplier therefore has to exercise skill in building on the special expertise that the relationship affords so as to develop services for a wider group of customers.

2.4.8 A track record through cost reductions

The third way to a track record is through cost reductions and process improvement. In most organisations this is, at least officially or formally, a key task for the operational management. This means that if outside suppliers are to be useful it appears virtually essential that they know more about the operation than its own managers do. This is, however, by no means unusual, especially in companies that own both the rights to exploit the resource, and conduct their own operations.

In such companies the core business is often felt to be closer to the resource evaluation end of the venture than to operations. In such companies the time that the more ambitious managers spend in any operational role may be quite short. Lending support to this observation, it is apparent that companies reputed to drive their technologies to the limit are generally seen as the benchmark for the industry rather than the norm. Such benchmark performance also tends to be found in operations where the resource is not good enough to allow any feeling of comfort in maintaining position on the industry cost curve.

So, the supplier may indeed know more than management (if not the operators). However, in such cases the benefit may have to be one that can be realised quickly because managers may be relatively uninterested in improvements that only show after they have moved on.

All in all, this is not an easy way to develop a track record for problem-solving expertise. It means getting into operations, which range between two extremes: at one extreme, the management is already very good at driving the process, and at another, where management is not particularly interested in improvement anyway.

On top of this, the financial authority limits of managers generally decrease approaching the point where the metal meets the rock. With this constraint, attracting the interest of the right level of management can be a major factor in gaining significant opportunities to demonstrate capability.

2.4.9 Track records for product suppliers and contractors

Making improvements in existing operations is generally easier for suppliers of tangible products than expertise. For example, a cheaper consumable will always attract attention. Unfortunately, however, a more cost-effective but expensive consumable (e.g. with a longer life) is a harder selling proposition. Overall, the nearer a product is to being the equivalent to a cheaper ‘bolt-on’ replacement for an existing function the greater its chances of being accepted. It is also likely that its potential for improvement will be less. Then again, if the supplier’s profits come from continued sales of consumables, too big an improvement may be a mixed blessing.

Although they deal with services rather than products, the success of service suppliers like contract miners and caterers fits the prescription above quite precisely. They can offer direct replacement of existing parts of operations.

Moreover, such contractors have no mineral resource to cushion any inefficiencies, so they have to be expert in their business. This makes them

promising targets for other suppliers of products to increase efficiency. Thus, the competitive supply industry spawned by an active minerals and energy industry producing commodities traded on the spot market itself generates a competitive industry supplying it with cost-saving products.

2.4.10 A track record by serving needs for compliance

The reason that the industry demands World-class services and products is that it is highly competitive in all three phases of the venture life cycle, around which this discussion is based. There are, however, other areas, typically to do with compliance, which are essential for continued access to resources and maintenance of the 'social license to operate'. At present these tend not to be seen as a bases for competitive advantage, although this might change. Safety seems to be moving towards such a position as companies contend for labour.

The most notable compliance field is environmental management.

Because it is not seen as competitive companies in the industry have been prepared to cooperate and jointly fund research projects to develop locally applicable expertise. This has three significant effects:

- **The lack of time pressure means that the pressure to use World-class expertise regardless of cost is reduced.**
- **The spreading of the risk by shared funding means that less well established groups can be given an opportunity.**
- **The need for local applicability gives a hometown advantage to those who are already working in the region.**

These same considerations mean that technology providers labour under corresponding disadvantage in attempting to capitalise on local experience to win work in other places. Their easier growth path is to extend their expertise to other industries working in the same locality, e.g. agriculture. Skills transferred to an industry where environmental management is more of a competitive advantage might then provide a better platform for expansion offshore than would a move into an overseas mineral or energy industry.

2.4.11 Going further afield

Groups that have successfully operated overseas, or even in Australia but far from their local industry customers, have found that it helps to have something tangible to demonstrate. Even if the ultimate aim is to export expertise, 'having a product is a nice way for people to visualise your skills'. The product is the hook; it is easier to sell a product than it is to sell people's time.

The fundamental competitive advantage that local suppliers have over would-be interlopers is that they have survived because their customers trust them. Breaking into a distant market means demonstrating better value and comparable trustworthiness. This means learning the networks, alliances, and contacts, and providing local follow-up. A successful, well-supported product can be used to develop trust at relatively low risk to the customer.

The message is that you have to have people on the ground. Again, there are two paths: organic growth, and a constructed enterprise. Given the global orientation of the minerals and energy industry, if you are prepared to wait long enough eventually there will be people who know you established just about everywhere. Thus, the long-established World-class centres can trade on a diaspora of satisfied customers. The university-based centres have alumni all over the world. Constructing an overseas business is most easily done by tapping into such networks. It isn't easy, but it is probably easier in Mineral and Energy than in most other industries.

Proof that this growth path is accessible is provided by the record of Austmine. Austmine is an association of export-oriented Australian companies (currently numbering 115) in the business of providing services, technology and equipment to the minerals and energy industry. They report export earnings of over $800 million for 1996, and this is certainly understated. Exports are expected to top $1 billion in 1998.

Formed a few years ago with a focus on coal, an increasing proportion of Austmine's membership is now based in Western Australia. This bears out the assertion by people in the banking sector that Perth is rapidly becoming, if not already, the World's leading centre of mining-related business activity. The driver is the highly competitive gold industry, confirming the analysis made above.

This does not, however, provide any grounds for complacency. Concerns have been expressed that reduction in exploration activity will have a dampening effect on mining production in the near future. The view has also been expressed that a number of companies in Austmine are now less inclined to see Perth as the most logical home base than they might have some five, or so, years ago. The argument is that a concentration of competitors is most valuable when products and services are in the development stage. Once they have become established this is less important a factor.

Furthermore, the need to maintain an overseas presence where the services and products are being used means increasing local recruitment in these places. Growth of in-house expertise elsewhere means that development occurs there as well as in the home base.

2.5 WORLD-CLASS CENTRES OF EXCELLENCE

Most suppliers of services and products to the industry have a home base where their competitive technology is developed, even if it is deployed, or its physical products are made, elsewhere. This is the 'centre of expertise', and some are recognised as 'World-class'. The subject of this section is the question of what it is that makes a World-class technology provider, or 'Centre of Excellence'.

The discussion here centres on the supply of external services to the exploration, planning, and operating phases of a mining venture. It doesn't deal with the engineering companies that service the construction phase of mining projects. It also leaves out, for the present discussion, in-house company research and technology centres operated by producing companies themselves, such as BHP, Rio Tinto, Alcoa, or Shell.

There are some external technology centres that everyone in the Minerals industry acknowledges as places 'where you go' to get a problem solved. For pilot plant facilities people immediately think of, say, Lakefield for flotation testing, Hazen for fluidised-bed work, Sherritt for pressure leaching, MEFOS for direct reduction, and so on (not to forget Amdel in Australia). In the Petroleum side of the industry companies like Schlumberger provide such expertise that they have become an essential part of the industry.

There are also other acknowledged centres of expertise, where industry can get a combination of experience and intellectual horsepower focussed on its problems, even if the testing facilities are less extensive. In Australia for example (and by way of report, rather than endorsement) the 'JK Centre' (Julius Kruttschnitt Minerals Research Centre, or JKMRC, Appendix E) is mentioned frequently as having an international reputation and clientele for mineral processing research in the wider sense.

People will also say they that they get work done in 'the University of XYZ'. A little further questioning will reveal that what actually happens is that they form relationships centred around particular individuals who happen to be in that institution. This is discussed further in Section 3.4. Similarly, work done 'in CSIRO' (Appendix E) will be found to be centred on a more specific internal centre within that large organisation.
It is clear that the acknowledged 'Centres of Excellence' have a head start in attracting additional business. Recognising this, and on the principle that success breeds success, Western Australian Governments have had in place for some years a program for supporting the development of Centres of Excellence. This has recently been extended to form one of the cornerstones of its current Science and Technology Policy. It has already distributed around $8m in funding, with about half of this going to the minerals and energy area. This considerable

faith placed in the concept makes a short examination of what it takes to develop such a Centre of Excellence particularly relevant

The examples listed above lead to the hypothesis that that two requirements for world class status are:

- unique facilities or expertise
- a track record of delivering value to the industry (customers)

The next two sections cover these in more detail.

2.5.1 Gaining a distinctive reputation

One grouping of acknowledged centres of excellence is characterised by hard-to-duplicate test facilities, as with, say, Lakefield. However, it would be misleading to think that duplicating the facilities would duplicate their success. The value of test facilities lies in their flexibility, and the speed with which they can be reconfigured to suit a particular customer's problem. This turns as much on the experience of the operating staff as on the hardware itself. Another critical factor is knowing what to measure in a test - a human skill. It is no accident that the test facilities named above have been around for many years.

The other grouping is based more overtly on intellect than facilities. The parts of this grouping come in two forms: the individual expert and the centre of expertise.

Uniqueness obtained through the expertise of a single individual is a precarious asset. It can fade away more easily than it can grow. The difficulty is that as problems are solved new ones spring up in unexpected forms, some of which will prove to be ephemeral, while others are more enduring and lead to the next set of major challenges. An individual has a hard time following all the leads, yet the leads have to be followed because it is not clear in advance which ones will be important. Taken over the whole research community it is likely that someone, somewhere, will be working on the right track, so the industry will get its answers. However, the former expert may no longer be in the limelight; the Centre may be eclipsed.

Maintaining a centre of expertise over any period of time is a real challenge. It takes a special person to meet this leadership challenge. Two descriptors that come to mind are visibility and credibility, both with the outside world, and with the individual contributors within the centre.

A sketch of a successful centre of expertise

It would be bold indeed to claim that there is a successful formula for maintaining a centre of expertise, but the technique of caricature may be suggestive.

Thus, we might see such a centre headed by a visible and credible leader who brings a coherent purpose to the whole. The Centre's programs are built around two or three leading lights at the very pinnacles of their professions and disciplines. Recognition by their peers is evident through the invitations they receive to present keynote addresses at leading international conferences and congresses.

The reputations of these core contributors ensure access to the latest and best equipment and technology. Their credibility lays the basis for patient and trusting relationships with innovative people from their leading-edge customers.

The presence of the leaders in two or three discipline areas is vital. It indicates that the nebulous, but important, concept of 'critical mass' has been achieved. Solutions to problems aren't necessarily found by greater specialisation in a single discipline; they emerge by assembling complementary skills. The World-class centre has a record of breakthroughs occurring at the boundaries of different specialisations. Perhaps the need is for 'critical variety' as much as critical mass.

Surrounding these luminaries we see a collection of acolytes and a guild-like assembly of apprentices and journeymen researchers. These are following the research leads, of which only some will prove to hold the keys to continued success for the centre. Recruiting apprentices is a major task for the leaders. If the centre is based in a university the leaders will not have heavy teaching loads, but will be found with undergraduates at critical career decision points, particularly in later years of courses.

The path for those aspiring to be future leaders in the field is very much 'up or out'. No more than about ten percent of the journeymen (be they PhD students or postdoctoral researchers) will make it to independent World-class master stature. Their service to the centre will have been in following the leads that might-have-been, but weren't, and in enabling the centre to meet the immediate needs of its customers. In return they will have developed transferable skills that they can take with them when they leave the centre. Some go to academic positions, many join the industry, and a few will leave to develop something they have worked on into a commercial product. These centres of expertise are focussed on selling research rather than products. Straight consulting and tangible product sales are spun off into separate ventures.

Even if this is accepted as a description, it does not explain how a centre might have got to such a form. The two most likely paths are:

- **organic growth around one or two individuals**
- **construction by combining existing elements, as in the formation of Cooperative Research Centres (CRCs, see Appendix E)**

A clue is found in the fact that the structure in the picture painted above is one that depends on a great deal of trust between all the participants: leader, researchers and those who expect to gain value from the Centre's work. Organic

growth is *prima facie* **evidence that trust exists. Construction leaves this test to a later time, and suggests that management of relationships have to be a dominant concern of management.**

Several discussions included the prospect of getting some 'JK Centre presence' established in Perth. The foregoing discussion provides a basis for considering such a proposal. For a start, it is clear that this would have to be much more than a mere 'shopfront'. The Western Australian industry has demonstrated that it is prepared to go to Brisbane for what the JK provides - about 35% of JK funding comes from Western Australia. Having a person to deal through in Perth will not be seen as adding value. Any such offshoot would have to be of a substantial size - the importance of getting enough people with different backgrounds together, rubbing shoulders, on the same site should not be underestimated. However, splitting the JK between Brisbane and Perth in proportion to funding might compromise critical mass.

Rather than moving a smaller offshoot to Perth and nurturing its growth, it has also been suggested that some sort of graft might be established with another group already present in Perth. This would put the project into the class of constructed centres, which as has been seen, brings it own challenges.

Such considerations would apply in the transplanting of part of any established group. It is not easy, and it doesn't happen successfully very often. The picture painted here points to some of the management issues involved. There is, however, another source of lessons.

All this bears strong similarities with what is seen in other fields, such as international management consulting, such as the McKinseys and the Andersens. Continued success in this model depends on having attractive ways out for those who don't make it to the top. The lesson from the big management and accounting consultancies is that only the few 'top-regarded' businesses can maintain the constant input of new talent, whilst ensuring good out-placements for the majority of them. The structure is based on a scenario of continuing growth, and there is only a few firms can maintain a place in the top league.

This analogy reinforces the lesson that the newly graduated PhD must be realistic about the opportunities for continuing a research career, especially as comments are already being made that "the industry is over-endowed with new PhDs seeking research positions". It is salutary to observe that this is being said at a time when so many research groups and CRCs are vying to become established. The research groups that will be best regarded in the long run are those that provide their people rewarding exit paths to wider industry and business opportunities.

2.5.2 Delivering value

The other aspect of gaining World-class stature in the industry is a track record, and delivering value is what the track record has to be about. It is certainly not about, say, delivering research reports. Delivering value means that industry's use of a centre of expertise has a real and positive impact on the business, and preferably, on the fortunes of the individuals who commissioned the work. This is what it takes to maintain the essential patient and trusting relationship with leading-edge customers.

Here again the organic growth model has advantages over the constructed alternative. A record of organic growth demonstrates not only internal trust, but also a continuing relationship with the industry that supports it. If it has survived and has grown, then a centre must have delivered value. Moreover, it can have started small, allowing a record of trust with its external customers to develop gradually in low-risk stages. Constructed centres have to establish a record at a high level of activity right from the start. This is a big 'ask'.

It is particularly difficult in a highly competitive marketplace for technology. Ability to deliver value is treated as a competitive advantage. Indeed, several technology providers made comments that threw some light on what they saw as their strengths in this area, but specifically requested that these should not be disclosed.

Competition between providers does not receive much explicit acknowledgment. Yet even their apparent openness in insisting on the right to publish new findings may sometimes be an aspect of competition. It is hard to compete for new staff (or students) when advertising is restricted. Competition is real, and getting tougher.

2.5.3 Supporting Centres of Excellence

The Western Australian Centres of Excellence program is aimed at developing research infrastructure, defined as those resources that allow research programs involving a number of projects to be conducted. It extends to personnel, equipment, building fit-out, and in some instances, building construction. Most of the support has been in the range $0.25 m to $1m for capital and equipment, notably in Cooperative Research Centres. That smaller sums are also available to assist in the preparation of applications for larger grants is comment in itself on the resources that researchers have to put into the search for funds.

This State funding is intended to be additional to other funding, although it can be used to leverage funds from other sources. Generally State funding is limited to 50% over a three-year period. The Centre, however, is expected to have a minimum life of five years, and must provide a business plan showing how funding during and beyond the period of State support is to be sustained.

Drawing together the discussion in the previous two sections, the conditions for maintaining a world class Centre of Excellence in research seem to be:

- a group of world class researchers attracted to the Centre and held together by a very special person as leader

- access to the best equipment and technology to underpin the work of this group

- involvement with innovative people from leading-edge customers in a patient and trusting relationship

The State's program can be looked at in terms of these three conditions. Thus, regarding the first, without the involvement of the right people there is little to support. The second of these conditions is the one most directly addressed by the Western Australian Government's Centres of Excellence Program. The third should be covered by the State's insistence on a business plan. It would seem that researchers are not yet entirely familiar and comfortable with this condition, but the motivation behind it is plain enough: untied Government funds have not in the past proved to be any guarantee for achieving world class stature.

An area that does not, however, seem to be explicitly addressed is a Centre's ability to regenerate its intellectual capital. As pointed out above, sustaining a Centre over a substantial period is great challenge. Its requirements for periodic injections of funding for people and equipment will test the "patient relationship" of the Centre with its supporters. Moreover, this would be increasingly subject to pressure according to the 'bottom-line'-driven scenario for the industry, outlined in Chapter 1. Centres, and their customers, need to become very realistic about the true costs of their sustainable operation. If they do not, governments can expect that they will be called on repeatedly either to replace capital or to fund the start-up of new Centres to replace those that will have predictably failed.

2.6 ATTRACTING CENTRES OF EXCELLENCE

States are naturally attracted by the idea of acting as home base for Centres of Excellence. Their presence increases the state's population, and specifically its population of technically competent people; this has an effect on the state economy through demand for housing, food, services, etc. Moreover, if the centres' services are in demand they bring more business to the state. However, these economic effects are driven by population increase and have little to do with the nature of the centre's work.

There is a greater benefit when such centres are tightly linked with local suppliers of services and equipment, which they use in their own services. There is even more benefit when their services are applied to improve the competitiveness of the local mining and petroleum industry. These are more important, but harder to quantify than the benefits from population growth.

Examination of the reasons for a company's choice of location for a corporate research or technology centre can be instructive to Governments and others who seek to attract such concentrations of expertise. The histories of their interactions with the rest of the minerals and energy community can indicate whether expectation of stimulation of the surrounding economy are likely to be fulfilled. This is also relevant to the forthcoming establishment of a CSIRO research centre, discussed in Section 2.7.

The record shows that there is no guarantee that bringing such a centre to a particular location will result in much direct business for local suppliers of technological expertise. The corporate culture in the centre is a critical factor.

2.6.1 Deciding to establish a corporate technology centre

A company's decision to establish a corporate research or technology centre is governed by its perceptions of the competitive advantage that can accrue from proprietary technology. This usually grows from a record of success with smaller technological developments, the prevailing attitudes among senior management, and the nature of the business. These have been discussed in other sections.

The analysis in terms of the way that the product is sold (Section 2.2.4) indicates that the products tailored for a particular market contract are the ones most likely to involve proprietary technology. LNG and alumina provide notable examples. Interviews revealed two examples where the proprietary demands of the alumina industry have resulted in expansion of Australian in-house R&D. In the case of Comalco, the withdrawal of Kaiser from the industry meant that the Australian operation, which had relied on a technology agreement with the American Company, was left to fend for itself. The proprietary nature of the industry meant that Comalco could not form other alliances, at least on attractive terms. The result was a significant and rapid expansion in its Melbourne laboratories.

Similarly, a decision by Alcoa in Pittsburgh to move out of the upstream end of the business (since reversed) left the local subsidiary exposed. It responded by developing at Kwinana what had been a small laboratory supporting the operation into the technology centre for the group's operations across the world.

The Rio Tinto Technology Perth facility (formerly CRA Advanced Technical Development) provides another case study in which corporate directions have changed. This facility was opened in 1989 and grew to about 80 people by 1996, making it a very significant centre by local standards. However, in mid-1997 it was wound back to about 40 people in a reduction that was specifically selective in terms of technology areas. The sections that dealt mainly with engineering improvements in production operations were closed. It was explained that the company no longer saw a competitive advantage in doing such development work in-house when it could be outsourced to other technology and research providers. The areas that were retained deal with knowledge management and process modelling. Changes on a similar scale were also made in the company's two laboratories in Melbourne.

What changed in the period between 1989 and 1997? In this time CSIRO, a major potential supplier of technology services to Rio Tinto, has certainly become more oriented towards commercial work for external clients. However, the decision to re-focus in-house capabilities appears more directly linked to changing managerial perceptions of competitive advantage, rather than to a greater availability of capable external research providers.

This example repeats what has been seen in the growth and decline of corporate laboratories in the minerals industry in the North America over the past decade or so. Technology is just one component of business strategy, and setting up a corporate facility competes for capital with other potential investments. Moreover, the North American experience suggests that a decision to reduce in-house technology capability is likely, and for similar reasons, to lead over time to a reduction in total expenditure on technology development.

2.6.2 Decision on location

The reason that Alcoa chose Kwinana for its technology centre was that the management considered it highly desirable, if not essential, to site the centre at an operating refinery. Given this requirement, Kwinana was the refinery closest to Perth; it was felt that it would be more difficult to attract the appropriate staff to settle in, say, Pinjarra.

This illustrates the point that such centres have to be located where research people are happy to live, especially if they are asked to relocate. To state the obvious, people in Australia take moving cities very seriously, especially when they have children at school. Reports of several recent experiences indicate that over 50% of staff may choose to resign rather than transfer. Thus the importance of the desirability of the location can hardly be overstated.

A few years ago BHP moved its laboratory in the United States from Sunnyvale (in Silicon Valley, California) to Reno, Nevada. It has been explained that Sunnyvale had become too expensive for staff, and the environmental discharge limitations had become prohibitive for the sort of work being done. However, the main attraction of Reno is said to have been that it is place where people were happy to relocate - 'close to Squaw Valley, and a 30-minute flight to San Francsico'.

At around the start of the present decade Rio Tinto (as CRA Ltd) set up its Technology facility on Technology Park, and established the HIsmelt Research and Demonstration Facility at Kwinana. These decisions to locate in Western Australia are acknowledged to have been influenced by the need to offset obligations to the Government to establish downstream processing, agreed to as part of the cost of access to the State's iron ore resources. Kwinana offered a particularly convenient industrial site, but the decision to locate both facilities in Perth rather than in, say, the Pilbara reflects the preferences of the people whom the Group wanted to attract.

2.6.3 Local linkages

The prospects of interaction and close linkages with the local technical community need to be regarded without undue optimism. In the case of the BHP move to Reno it is reported that there were no particular prospects of interaction with the local university or other potential suppliers. Similarly, by all accounts the HIsmelt operation has had little interaction with potential suppliers of research services in Perth, although work has been done by CSIRO in Melbourne, and in overseas universities.

It appears that in neither case was access to local expertise a significant concern. The HIsmelt view on the lack of engagement is that local researchers haven't tried hard enough; the researchers say that they were told the research was proprietary, and ask: "what were we to do?"

There is a rather similar record with the Rio Tinto Technology facility in Perth. One external research group (not Perth based) is said to have "knocked and knocked and finally kicked the door down", but generally external research providers have not obtained much work there. There is often a simple reason for this. Increasingly, corporate research centres are losing corporate funding; they have to seek funds from operating divisions within the corporation. They may find themselves in competition with external research providers.

Where external providers can get work through such centres is where they have particular expertise or facilities that it would be uneconomic for the corporate centre to duplicate. Alcoa has a strong record of working with local universities.

Thus no matter how proprietary the technology there is always the possibility of collaboration with local providers. Whether or not it actually happens seems to come down to individuals and the corporate culture prevailing within the centre. If the attitude within the corporate facility is that it is self-sufficient in expertise, then there will be little incentive for working with outsiders. However, even against such an attitude a local research supplier with a suitably unique 'angle' may be able to prevail, given sufficient persistence.

Extending the accounting of benefits to the State a bit further, the number of people brought to Perth by Rio Tinto Technology (ATD) and by HIsmelt, and who have since left to join other local companies is now considerable. This has had the effect of boosting the number of technically competent people with an industry background working in the local economy.

2.7 THE CSIRO PETROLEUM AND MINERALS RESOURCES RESEARCH CENTRE

CSIRO stands in a unique position in Australian research. While a few corporate research laboratories and university centres are able to match its facilities in specialised areas, no other organisation can command the sheer volume - both breadth and depth - of expertise that CSIRO can muster.

It is generally acknowledged that CSIRO has a commitment to excellence in its people and its equipment. CSIRO is also currently committed to merging its centres into units of substantial size. This means that it can start with the essential ingredient of critical mass. Also, and increasingly with its recent reorganisations, it is co-locating experts in differing discipline areas within the one centre. Variety of background - the other ingredient for a World-class centre - is made possible. The attractions to a government of having a major CSIRO centre based in its State are clear.

The Western Australian State Government and CSIRO have recently come to an agreement that will establish a CSIRO National Centre for Petroleum and Mineral Resources Research in Perth, in the Bentley Technology Precinct. This has similarities with the arrangements between CSIRO and Queensland that brought major CSIRO facilities to Brisbane.

In support of the arguments in favour of such a move (discussed in Section 2.6), large economic benefits have been claimed for the Queensland move. They certainly help the justify the expenditure of public money in backing the move, even though the figures seem to be based mainly on the economic multiplier effects of the migration of staff to Brisbane. The outcomes that they focus on are those that are easily measured (or calculated). It is harder to say what effect the

move has had on the industry or on the local technology base; there is a general sense that it is seen as being positive.

In the case of the developments in Perth there is a certain amount of concern about CSIRO's relationships with others in the local research community. However, the decision to locate the centre on the Technology Park site is generally seen as a very positive way of facilitating productive interaction. On the customer side, the onus is now firmly with the industry to support the centre so that it can develop a strong focus on local technology needs.

2.7.1 The context to CSIRO's expansion in Western Australia

The Western Australia State Government has arranged what amounts to a concessionary loan of around $35 million to move Exploration and Mining from Floreat Park and to establish Petroleum Resources with it on a site in the Bentley Technology Precinct. As part of the deal, the minerals and energy industry has indicated that it will place a substantial amount of work with CSIRO. The Division of Minerals has a presence nearby at Waterford, which it plans to expand.

CSIRO is dominant in minerals and energy research in Australia, specifically through its Divisions of Exploration and Mining, Minerals, and Petroleum Resources. In addition CSIRO is involved in many Cooperative Research Centres (CRCs) thus forming links with various local university departments. However, only in recent years has CSIRO moved to become a correspondingly large supplier of research expertise to the industry. This change has resulted in CSIRO's taking a competitive stance in the market for research services. Running a CSIRO Division is now seen as running a business.

The background to this change started several years ago when CSIRO's apparent lack of concern for current industry issues had become a significant political issue. The Federal Government, to which CSIRO is ultimately responsible, imposed a regime requiring a minimum of 30% external 'non-appropriation' funding (i.e. from sources outside the Federal Government budget for CSIRO). The intent was to make CSIRO more responsive to the needs of industry, while retaining a capacity to perform longer-term fundamental research in the National interest.

However, and emphasising the point that CSIRO is not a homogeneous organisation, the Division of Exploration Geophysics is said to have had over 60% of its funding from industry during the late 1970s, well before concerns about responsiveness had been converted to targets. Overall, in the Divisions concerned with minerals and energy the 30% requirement has been surpassed

and external funding is running as high as 50% (not all of this need be from industry, some can come from other government sources outside the CSIRO appropriation). This figure matches the target proposed in the Mortimer Report to be achieved by all of CSIRO by the year 2005.

2.7.2 CSIRO's status and its change to a more commercial stance

CSIRO is big and has the potential for World-class centres of excellence in several fields. The most significant developments in the Australian minerals and energy industry (outside in-house corporate laboratories) have originated in CSIRO. Significant ventures have also been spun-off from CSIRO work. For all that, it is interesting that CSIRO does not receive the immediate recognition as "the place to go" that might be expected. Where this acknowledgment is accorded CSIRO it is often through association with a CRC. There seem to be several reasons for this.

The first is that the until recent times CSIRO did not have to seek work from industry, and generally it did not do so. Not surprisingly, though with exceptions, those in industry who used CSIRO in former times often complained that the organisation was not responsive to commercial pressures and realities.

Another reason may lie in CSIRO's past tendency to locate laboratories in several States. This may have satisfied some local aspirations, but has worked against achieving the desirable concentration of resources on the one site. For example, the Division of Minerals currently has six laboratories throughout Australia. It is in the process of concentrating this into three, but even this may be stretching resources more thinly than is desirable.

The benefits of the new developments in Perth flow both ways; they are an opportunity for CSIRO to ensure that the desirable concentration is achieved. However, no doubt there will be tests placed on CSIRO's resolve by other State governments also seeking the envisaged benefits of a CSIRO presence.

A third reason for CSIRO's lower than expected profile in industry is that the size and the number of centres mean that CSIRO presents many different faces to the world. It is arguably as difficult to speak meaningfully of CSIRO as it is to speak of the minerals and energy industry. Times are certainly changing for CSIRO, and the changes go deep into the social culture of the organisation. It should not be surprising that all parts of it may not have moved towards a more commercial orientation at the same pace.

One example of its culture is that CSIRO used to be a rather inward-looking organisation. Examples cited suggest that location of CSIRO activities adjacent to universities in other states has not resulted in the expected productive

interactions. Indications of State government encouragement of collaborative interactions with CSIRO and other public research institutions have therefore been well received by those who express concerns about this.

2.7.3 CSIRO as a commercial research provider

One of the more intriguing questions about CSIRO's change in outlook is whether, as well as being known as World-class, it can actually become a supplier to the World. There are restrictions on what it can do in this field. A large proportion of CSIRO's funding still comes from the Federal Government in order to improve the Nation's industry, rather than to improve the efficiency of its competitors. Nevertheless some work is done for foreign companies under trade-offset agreements at 'full cost'.

The question of CSIRO's costs is quite important now that the organisation is becoming more active in the research supply market. The owners of private-industry R&D facilities had long been critical of CSIRO for allegedly undercutting them by undercharging for research. This would appear to have been corrected by the current rate structures, which are more comparable with their competitors. However, the argument of effective undercutting is still being advanced.

Thus, a requirement for 30% industry funding would suggest that the Government had intended that 70% of CSIRO's research would be long-term fundamental research in the National interest. It is, however, claimed that most of this 70% goes into supporting or subsiding the industry-funded component. On this basis, it is alleged that a Division that gets 50% funding for projects paid for by industry is not actually doing much other 'National interest' work of any consequence.

This might be of little concern to the industry; it would improve the value it gets for its money. However, other research providers, privately and publicly funded, believe that the public funding component means that CSIRO has at least some responsibilities that would not apply to a fully privately funded research supplier. For example, CSIRO possesses a tremendous depth of talented people. One of the advantages of CSIRO involvement in CRCs is said to be that a relatively small investment can be used to leverage considerable value from access to this pool. However, the combination of size and competitive approach to getting business has put some strains on the partnerships that were envisaged for CRCs.

2.8 THE VALUE OF LOCAL TECHNICAL EXPERTISE

The remote location of mineral and oil finds means that ventures are often established with little or no existing infrastructure and no local expertise. Even corporate technology centres can be established as self-sufficient enclaves, having little interaction with the local technical community.

The petroleum industry, in particular, makes heavy use of expatriate employees. Some would argue that in doing so it tends to overlook the availability of local expertise.

Nevertheless it is universally acknowledged that it is "nice to have" local expertise available. This does not apply only to potential employees; it is also acknowledged that it is desirable to have access to a local community that is expert in the technology of the business. Thus: "it was a bit of a blow when X left the university and joined Company Y; now I've got no one I can talk to about these problems." And: "going to conferences, technical workshops, and university seminars gives me the chance to benchmark our work."

However, the local availability of expertise is definitely on the second tier of any checklist of criteria for locating a mine, a head office, or even a technology centre.

2.8.1 The price put on local expertise

Just how much is such a nice-to-have feature worth? Clearly it will depend on the company, but an answer may be gleaned from the following:

"We've been prepared to put, say $30 000, into MERIWA projects [Section 3.2.2] to keep the [university] department interested in our problems. You never know when you might need some help. But I could only convince the Board to give, say, $100 000 if we had a real problem to solve, and this would have to be done properly with real deadlines and proper project management."

This seems to mean that this fair-sized producer considers that maintaining some focussed local expertise is worth maybe one $30k project per year; other smaller producers are prepared to subscribe $10-15 k. These expenditures are made without any particular sense of needing to formally account for the possible benefits that the research might bring. It's almost, though not quite, as if any tangible beneficial outcome would be regarded as a bonus. It is not a retainer, and yet in some ways it is more valuable to the academic, and arguably almost as useful to the company.

Another company is said to spend about 2% of its R&D money on such 'holding' projects, though having operations in several places it does not limit its investment to locals. It is also prepared to advance somewhat larger sums to World-class research groups in order to maintain their association with the company's possible future needs.

Pressed for a figure, one gets the feeling that the value of maintaining local academic expertise is placed by mining companies at somewhere in the range of 10% to 20% of the salary of the academic in charge of the project.

2.8.2 Professional and Technical Institutions

Professional institutions and technical societies play an important role in providing a forum for exchange of expertise. Their meetings provide a neutral ground where people from different and competing organisations can interact 'legitimately'. Visiting speakers can also be brought in to inject expertise into the local technical community at large.

There are many professional institutions and technical societies active in areas relevant to the minerals and energy industry, and multiple membership is quite common. Many professionals also maintain allegiances with UK- or US-based bodies. Local branches are notably active in mining communities, where their meeting content is predominantly technical. Meetings in the city have a similar social function, but their content is often less directly technical, reflecting head-office interests in other aspects of business.

A recent trend impacting on the institutions is the call for them to move towards certification and registration of competency as governments increasingly vacate the field of regulation. This is already in place within the Institution of Engineers, Australia (IEAust), and there are similar developments within the Australasian Institute of Mining and Metallurgy (AusIMM). This also links to their schemes for continuing professional development, which is a requirement for maintaining registration.

The trend towards requiring certification to practice is most advanced in aspects of engineering where the public is at risk, as (say) in structural design. The most notable examples of this in the minerals area are the regulations governing registered Mine Managers (as remarked previously), and restrictions on who can attest to estimates appearing in a company prospectus.

The IEAust continues to fight hard to restrict the use of the term 'Professional Engineer', but for the most part the professional bodies have few sanctions regarding the way people describe themselves, or how companies describe their employees. Both bodies accredit certain university courses. However this only means that graduates of these courses are eligible for graduate status in the professional bodies without further examination. Universities may (and occasionally do) choose to offer unaccredited courses. If the industry accepts their graduates then the courses will continue.

One may remark that there is a small but interesting difference between these two major professional institutions. The IEAust describes itself as a group of

professionals - 'engineers' - rather than as an institute of engineering. The AusIMM refers to itself as an industry group - 'mining and metallurgy' - rather than as an institute of the geologists, mining engineers and metallurgists who work in the industry. From time to time both organisations become conscious of the potential limitations of their coverage, but it hardly seems to have much effect in practice.

It is conceivable that institutions and societies will become increasingly important in the future as companies tend to reduce the number of their core staff, and more and more professionals become self-employed. People employed on this basis may well come to have a greater sense of loyalty to their professional association than to the company for which they are currently working. Institutions could increasingly provide the professional home base for development that was once ensured by being part of large company.

3 THE EXTERNAL RESEARCH SCENE

Much of the discussion about making best use of the State's expertise in applying science and technology in the minerals and energy industry concerns the State's external research capability. The internal research capability within the firms in the industry is a separate matter on which the companies make their own judgments. However, even businesses with their own internal facilities make use of external providers. Their capabilities thus have a potential impact on the success of the industry. It also has a vital bearing on the potential for the State to develop its research industry through attracting research work from a wider client base.

> **The observation made in the introduction to the previous chapter, that the industry does not appear to be markedly held back by the absence of research capability in this State, suggests rather that the presence of the industry represents a market opportunity that local researchers might pursue. It should do this while the industry is strong, bearing in mind that it is subject to cycles, and being extractive, its continued strength and even its presence cannot be taken for granted.**

The picture of the external research scene is displayed here in seven sections. While the previous chapter dealt with research excellence, the dominant theme in this chapter is money.

1. **The chapter starts by giving a feel for how the industry makes use of research, and estimating how much it spends on research performed by external providers. It attempts to bring some reality to expectations that researchers and government funders may harbour concerning size of the industrial market for external research. It suggests that, overall, the amount of money available for external research providers may be around 0.2% of the value of the industry's production, and hence its conclusion is that:**

> **The size of the 'pie' is considerable, but it is not unlimited.**

2. **The second section introduces some of players in the external research game, and identifies their major sources of income. It also describes the role of two important research brokers.**

> **It is surely quite significant that researchers are described as 'seeking funding' from industry. The alternative of 'seeking to solve industry's problems' is rarely if ever heard.**

3. The third section discusses the nature of the relationship between industry and the external researchers. There are frequent and recurring misunderstandings, which need to be clarified. One of these concerns the value of money to the different parties to a research contract, and this is explored briefly.

4. The next section explores the process by which a university researcher might grow an embryonic capability into an established centre. The Julius Kruttschnitt Mineral Research Centre within the University of Queensland is used as a model because of its long track record of continuing growth and the frequency with which it is mentioned as an example by people within the minerals industry.

5. This leads to the fifth section dealing with Cooperative Research Centres (CRCs). Getting research funding is always a challenge, and the real test of viability is whether a centre can sustain its funding base.

6. Some of the ways researchers go about getting the funded work that they need to maintain viability are covered briefly in the sixth section.

7. The chapter concludes with a short section speculating on the future of the traditional PhD system.

3.1 INNOVATION AND RESEARCH IN INDUSTRY

In a paper presented at the International Mineral Processing Congress in October 1995, Batterham and Algie pointed out that minerals businesses may spend relatively little on research, and yet be quite innovative. In coming to this conclusion they had adopted a formulation defined by the Australian Industrial research Group:

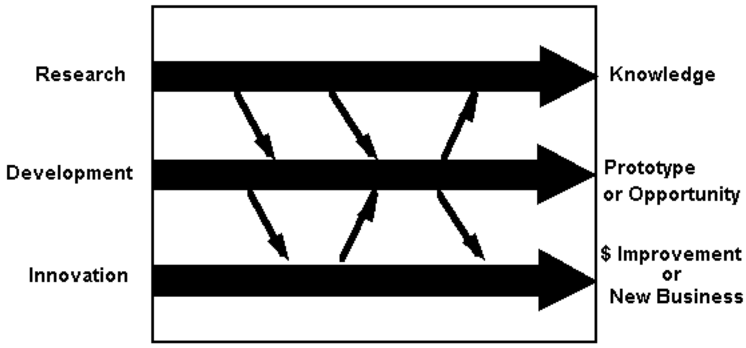
Valid Business Strategy + Improvement Culture + Innovation → Sustainable Competitive Advantage

They had also accepted the definition of innovation used by the Business Council of Australia (Carnegie and Butlin, 1993):

In business, innovation is something that is new or improved done by an enterprise to create significantly added value either directly for the enterprise or indirectly for its customers

Innovation can come from adaptation of technologies to the business, purchase from other developers, hire of knowledgable people, etc., as well as from research and development (R&D). Indeed, their study of innovation suggested that research, development and innovation are separate processes. Thus they wrote:

Whilst the connections are frequent, (as shown in the [following] figure) they are on an as-required basis. It is very clear that innovation can proceed without any research or development and that it is innovation that generates the competitive advantage, not the research and development *per se*.



They also noted that:

the activities of research, development and innovation are separate enough to involve different values, mores, peer groups, reward systems and funding arrangements.

In general usage, the terms 'research, 'R&D', and 'science and technology' tend to be applied interchangeably to all these related but distinct processes. In the interests of convenience the term 'research' will generally be used here without distinction, however, the imprecise nature of the term should be borne in mind throughout the following discussion.

3.1.1 How much money does industry spend on research?

Batterham and Algie presented data that indicated that in 1992 large companies in the minerals industry typically reported R&D spending equivalent between 0.5% and 1% of sales revenue. Higher proportionate spending was generally associated with business engaged in 'downstream' production of metals and finished products. There are deficiencies in the data; companies are not consistent in what they class as R&D. Nevertheless, it seems reasonable to conclude that a generous estimate of 'research' spending, in the general sense, is 1% of sales for the industry as a whole. It is not, however, possible to distinguish between research and development spending from available figures. Even within companies no distinction is made in recording R&D spending.

Much of this is spent in-house in corporate laboratories. A bold but not unreasonable assumption would be that, averaging over companies with and without corporate facilities, of their 'research' funds would be potentially available to external research providers. Where there are corporate laboratories the amount spent with external research providers seems to be around 10% of the total. BHP is reported to be currently aiming at 30%, but this has not yet been

attained.. Working on the figure of 20% outsourced, and 1% spent on R&D makes the amount equal to 0.2% of revenue. On this basis, the $10 billion Western Australian mineral industry might be spending $100 million per year on 'research', with $20 million per year going to external research providers, not all in Western Australia.

No figures were to hand for the energy industry. However, a comparable figure applies within the Australian export coal industry. A levy of 5 cents per tonne is charged and made available for Australian Coal Association Research Projects (ACARP). The total sum form industry is about $9 million per annum, which is around 0.1% of revenue, and this is leveraged up by a factor of about 2.8 with public sector funding. The research itself is contracted and managed by AMIRA (discussed in Section 3.2.2) and the funds are available to bids by research providers. Even though some of the research ends up being done in corporate laboratories, it is potentially available to all. Coal companies do not appear to make much other funding available to external research providers.

The status of the levy is rather complicated. It was previously compulsory but now applies for a fixed term and is formally voluntary, though all companies pay it. The companies themselves argue against it, but their own audit found that it had resulted in innovations with a value far exceeding the cost. It is also reported as being favoured by management at the operating sites. They apparently did not consider that they would have been able to convince their senior management to spend as much on research without it.

The companies arguing against it say that they should be the ones who decide whether or not to spend money on research (although, as noted, lower level management doubts that they would spend as much). However, since the levy is being paid, the system of AMIRA management in which the companies make their cases for what should be studied, and the research providers bid to do the work, seems to be well accepted. If the research favours one company over another it is only because the others companies haven't made a sufficiently good case, in a competitive environment, for different work to be done.

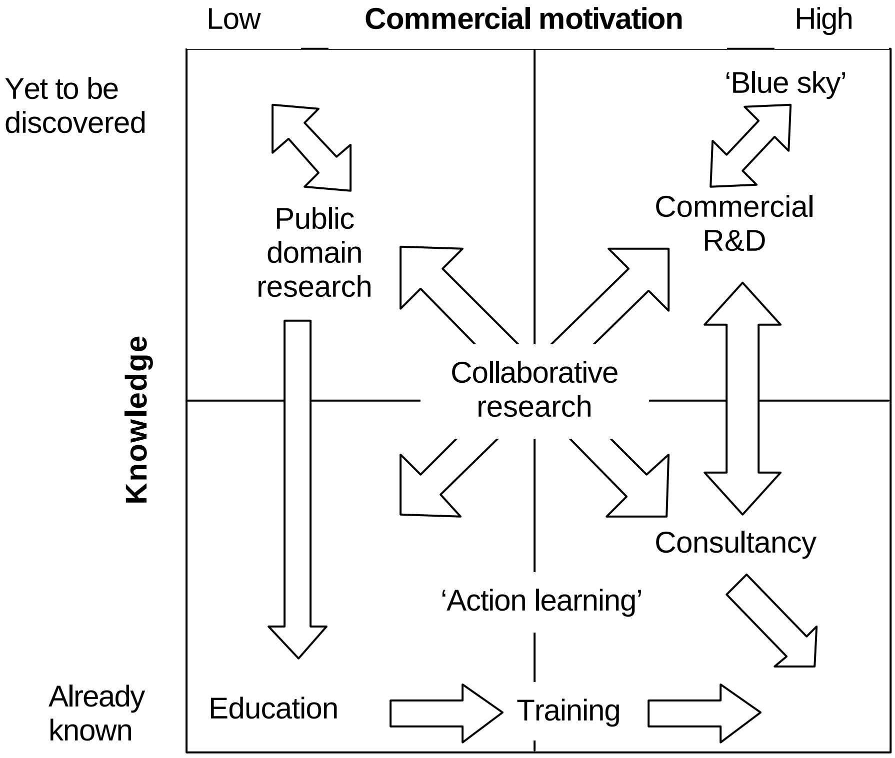
Suppliers to the industry generally spend relatively more on research and development than the producing companies. The 1995/96 Austmine survey of members showed that 30% spent more than 5% of turnover on R&D, while another 37% spent between 2% and 5%. Some, notably software developers, spent over 20%. These levels are well above the average for most other industries in Australia.

Another piece of evidence is significant. The JKMRC has found that the funding that it gets from the different States in Australia is roughly proportional to the size of each State's mineral industry (35% of its funding is from Western Australia). The work available to external researchers does seem to be related to the size of the 'pie'.

The size of the 'pie' is considerable, but it is not unlimited.

3.2 THE EXTERNAL RESEARCH GAME- RECOGNISING THE PLAYERS

There are many ways of generating knowledge and using expertise, and most of these can be described (and sometimes are even passed off) as 'research'. The following map attempts to place some of these ways in the context of the newness of the knowledge involved, and the degree of commercial motivation. It also indicates some of the directions in which the various modes of use tend to lead.



There are many ways of using and generating knowledge and expertise

Allowance should be made for the caution expressed earlier about the confusion between research, development and innovation. However, taking this into account, the research needs of industry, and the services offered by research providers, range widely over this field.

This section points out the main characteristic of the players in research for the minerals and energy industry. It largely ignores the distinction between research, development, and innovation, and does not attempt a comprehensive identification of the specific players.

The following table lists eight main types of player in the research game, together with a few examples, listings of the types of owner, and an indication of what they do.

Type	Examples SEE NOTE BELOW!	Owners, stakeholders	Indicative capability
'Solo' researchers	University academics	Universities	Research
Consultants	University academics, university consulting companies, private individuals, consulting companies	Various	Research Small-scale test work
University-based centres	Centre for Strategic Mineral Deposits (UWA), JKMRC (Qld), etc.	Universities	Research, Small-scale test and pilot plant studies
Government research institutes	WA Mineral Processing Laboratory, CSIRO (WA and other States), etc.	Federal or State Government	Research, Pilot plant studies (may do commercial test work)
CRCs	A J Parker, CMTE (Qld), etc.	Universities, CSIRO, Industry	Research, Usually have access to pilot plant capabilities
Commercial research and pilot testing laboratories	AMMTEC, Amdel (SA), Mintek (South Africa), etc.	Shareholders	Research, Commercial test work Pilot plant studies
Commercial testing laboratories	ALS, Analabs, Oretest, etc.	Private or public companies	Commercial analysis May include test work
In-house corporate Laboratories	Alcoa, Rio Tinto (WA, Vic, overseas), BHP (Vic, NSW, overseas) etc.	Parent company	Research, Test work Pilot plant studies
Corporate development projects	HIsmelt Research and Demonstration Facility	Parent company, joint ventures	Research, everything up to full scale production testing
Research brokers and managers	MERIWA, AMIRA (Australia and some	Shareholders, Government	Arrange consortia of funders and

	overseas),	authorities	providers, manage projects

NOTE: Examples in this table are intended only to indicate the range, types and locations of research providers currently used by the Western Autralian industry! Operations are in Western Australia unless otherwise noted.

There is an urge to extend this table by listing specific areas of expertise currently available in the minerals an energy field. This has been resisted. Essentially it is too big a task. However, there are some other justifications.

People will say things like "the University of Tasmania is strong in ore genesis". Pressing harder, it turns out that (in this instance) they mean that the Centre for Ore Deposits and Exploration Studies is good in this field. They then go on to mention that they are really talking about Ross Large in particular, even though this is no doubt unfair to other able people in the Centre. A similar chain runs from, say, UWA, through the Centre for Strategic Mineral Deposits, down to David Groves. Universities only have strengths in as far as they are home to certain centres and people. You don't go to a particular university for research; you go to a centre, or (most likely) to an individual. Much the same can be said of contacts with CSIRO.

This quickly leads to an unwieldy and constantly changing list of sources of expertise. Recently in UWA 11 centres, groups and departments recognised that they are all working on projects funded by the minerals and energy industry. They have now put together a brochure and capability statement. It is said that the University itself had no idea of the extent of this engagement with the industry. The only way to find out who is doing what for whom is by extensive survey, and even then it is certain that someone will have been left out.

As one comment put it, the situation is "complex and dynamic and should remain so ... they should come and go all the time ... it is no good relying on past records of success".

The following sections go on to give a pen-picture of how the world of external research providers to the minerals and energy industry operates.

3.2.1 Where their money comes from

Researchers may be able to approach their owners or employers for research funding. Thus universities often make some funding available to staff, especially new staff, mostly on a competitive basis. In the case of CSIRO a proportion of its research is paid for directly from the Government appropriation for operating the organisation. Until a few years ago this used to be nearly 100%, but is now

targeted to be less than 70%; some minerals area Divisions are said to have reduced this to less than 60%. In-house corporate laboratories normally run on a mixture of work paid for by operating units within the business and corporately funded projects.

Outside the use of these internal funds, the main external sources of funding for which these researchers compete, include the following, though not all sources are open to all classes of researcher:

Federal funds:

- Australian Research Council (ARC), including its Special Research Centre Scheme
- Australian Postgraduate Research Awards (scholarships)
- CRC funding provisions
- Special schemes and funds, e.g., for university Centres of Excellence
- Individual research contracts from Departments

State funds:

- Individual research contracts from Departments
- Special schemes and funds, e.g. MERIWA (Section 3.2.2)

Industry funds:

- ACARP coal levy
- Individual contracts with companies
- Jointly-funded contracts from industry consortia

In addition, researchers may be able to use funding to attract, or 'leverage' additional funding or concessions, such as, the 125% taxation incentive, matching of funding from industry and other Governments, etc.

Funding for research within the university system seems to verge on the arcane. On some occasions funding from industry for postgraduate research has had a remarkable leverage through its Federal Government funding formulas. This can change a particular university's proportionate share of the limited total funding. It's the same pie (for the whole of Australia), but that university can then get a bigger slice. Western Australian universities are said to have been generally disadvantaged by such formulae. Furthermore, internally the additional funds do not necessarily flow directly to the departments or centres that generate the external income.

It is surely quite significant that researchers are described as 'seeking funding' from industry. The alternative of 'seeking to solve industry's problems' is rarely if ever heard.

3.2.2 The collaborative research brokers and managers

The two organisations in this class that are discussed here are AMIRA and MERIWA. The Australian Mineral Industry Research Association (AMIRA) is a company limited by guarantee comprising as members of the association, companies in the minerals and energy area. A linked organisation covers the Petroleum Industry (PIRA), but this has not been as significant a player. For nearly 40 years AMIRA has operated by identifying common research needs from among its members, and identifying research providers who might be able to resolve them. The providers then draw up proposals, which are circulated among the members, and if all goes well, as consortium of interested members will share the costs and the results. AMIRA manages the progress of the research on behalf of the sponsors.

The Mineral and Energy Research Institute of Western Australia (MERIWA) is a statutory body, which has existed in various forms for about 15 years. It is different from AMIRA in that as well as providing a broking and management function it distributes State Government funds. The ‘sweetener’ of having State funding to distribute has resulted in MERIWA being able to attract industry funding equal to about twice the Government amount. Some projects have a single industry sponsor; other are funded by consortia. however, in all cases the results are published and are freely available. In this its operations have some similarities with ARC collaborative research grants.

The scheme is limited to Western Australian researchers for Western Australian projects. Research providers in other States have been heard to criticise this on the grounds that Western Australian companies should be encouraged to have access to the best available expertise (presumably theirs!). MERIWA has, however, always had a partial aim of directing any under-utilised Western Australian research capacity towards local industry development, and thus to ensure that the results of research are useful to industry, and available to it through publication.

Some companies have been able to get great value from collaborative ‘pre-competitive’ work performed through MERIWA and AMIRA. The ideal situation has been when a sponsoring company (perhaps every sponsoring company) already has some in-house knowledge. Getting access to, say, test data from a wider range of operations than their own lets them leverage this knowledge. Their prior work gives them a unique context, and context is what turns mere data into potentially valuable information. The hope of the companies is that the other collaborators, lacking context, might not be able to make as much as they can out of the research data. As an observation, in larger companies collaboration, as through AMIRA, is essentially optional. Smaller and medium sized companies have less choice other than to collaborate and benefit from the leverage available. The ‘junior explorers’ generally cannot afford to participate in collaborative activities.

AMIRA projects tend not to be short studies. There is a considerable overhead involved in getting a project off the ground, so a year's duration would be a practical minimum. At the other end of the scale one AMIRA project ("P9") has a continuous history over 36 years, in a succession of three-year, and shorter, sub-projects (with a succession of sponsors) building around a common theme of mineral processing.

The AMIRA system has worked very well for over 30 years; as noted, AMIRA has been given the contract to manage ACARP funds on much the same basis. However, the changing times are catching up with this 'traditional' AMIRA system. Companies are reportedly less willing to collaborate than they were; fewer areas of research are now seen to be 'pre-competitive'. On top of this, AMIRA detects a general hardening in company attitudes to research spending; faith in technology as the key to competitive advantage seems to have waned in senior management thinking.

The areas in which AMIRA projects are being developed are therefore moving to less directly competitive compliance fields, such as environmental studies. These are critically important, especially in terms of the 'social license to operate', and may often be run jointly to mutual advantage. The field of operational safety is also emerging as one where mining companies will have no choice but to improve. However, it remains to be seen whether they will regard this as pre-competitive compliance work or as a source of competitive advantage. The decision will determine whether AMIRA and MERIWA move into this area.

The other change is that research providers are becoming more competitive in seeking funds. They increasingly want to 'get closer to their customers' and tend to see AMIRA as an unnecessary barrier between them and the sponsors (this doesn't apply to MERIWA because it is itself one of the sponsors). The role for AMIRA is generally less when one-to-one research is done by a single research provider for a single company. In such cases the AMIRA management fee (roughly 10%) tends to be seen as non-value-adding. Managing research projects does, however, cost time and money. The conclusions that may be drawn from this reluctance to involve AMIRA are that some companies believe that they can do it more efficiently than AMIRA does, or that they don't realise how much effort it will take to do it properly.

To put AMIRA's role into perspective, it has never handled more than 5% of total industry research expenditure. Moreover, its members have regarded this as seed investment leading to further one-to-one or in-house developments.

MERIWA is experiencing some of the same problems that have befallen AMIRA. The current projects certainly have a notable proportion of 'compliance' environmental studies. In another category are the geological studies, such as the genesis of deposits, in which interpretation in the light of in-house knowledge could be a significant benefit to a sponsor.

MERIWA and AMIRA projects have been a good way for many companies to get good returns from small investments, provided they are prepared to put in their own contribution to analyse the results. However, the changing times mean that AMIRA is having to rethink its strategy.

3.3 WHAT YOU PAY FOR IN RESEARCH AND WHAT YOU GET

Research costs money. There are costs in maintaining the infrastructure and the costs of operation. Research infrastructure ranges from intellect, through to capital-intensive pilot plants. Operating costs are incurred in paying the people, running the equipment, and supplying materials.

The costs of running a corporate laboratory, including support staff, typically works out at about $125k per professional researcher. This seems to hold in terms of local currency in Australia, the USA, and Canada. Depreciation of the specialised equipment often runs as high as about 15% of the total cost. These figures mean that when research is charged at “full commercial rates” its base cost has to be around three times the gross salary of the researchers who are working on it, before material costs are added. On the other hand, research may be obtained on other than full commercial terms. This is discussed below.

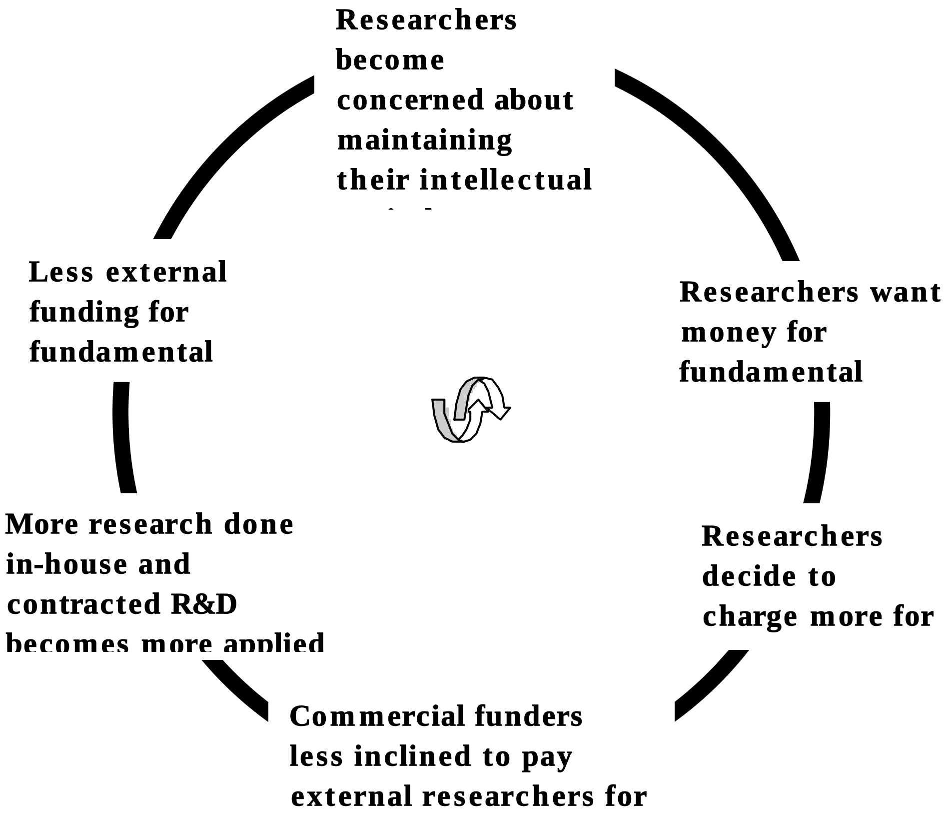
Building an operating a pilot plant is a very expensive operation, and lies well and truly on the development end of the R&D spectrum.

A rule of thumb puts the cost ratios for research, development, and innovation (commercialisation) as about 1: 10: 100 (at least). Research that uses mainly intellectual inputs and laboratory scale equipment and operations is thus cheap in the total scale of introducing a new innovation. However, if nothing comes of it, spending on research can be money ‘down the drain’ for the intending commercialiser. The more research relies on discovering previously unknown information, the more inherently risky it is. Thus whoever would make money out of research must balance the relatively low cost of research (in the whole innovation process) against the relatively low probability of success.

The application of what is known is less inherently risky, and many commercial investors prefer to limit their involvement to this aspect of ‘research’.

This leads to two sources of complaint from the parties involved in research. The commercial supporters complain that the researchers tend to have an inflated idea of the worth of the intellectual property (IP) value in any results produced. On the other hand, researchers complain that it is hard to get commercial funding for research into the unknown areas that provide them their intellectual

capital for future applied research. These are all partial truths, but they point to a vicious circle:



This model is based on some contentious premises that might not actually be true. Nevertheless, if people hold to a model they will base their expectations and interpretations upon it. Thus, the argument encapsulated in this diagram has a wide currency.

In the past, universities and CSIRO had usually charged external customers much less than the commercial rate per researcher (more like the incremental cost). The justification appears to have been along the lines that CSIRO's main business was long-term research in the national interest, and that industry input was helpful because it gave access to working plant, etc. According to this explanation, since industry involvement was partly in order to help out CSIRO, industry had not been inclined to pay the full price.

Universities have, until recently at least, always seen their main purpose as the preservation and increase of knowledge, and in its transmission by the process of education. Much the same as with the explanation offered for CSIRO's previous *modus operandi*. Funding from industry to work on industrial projects was seen as a contribution from industry towards the generation of knowledge, rather than as a way of improving the profitability of industry.

Times are changing, and now universities are being called on increasingly to use their store of knowledge to deliver immediately applicable benefits directly to industry. This is in addition to their indirect contribution through educating the next generation.

In both CSIRO and universities, the change in expectation has put strains on old ways of working. Whether or not the Nation received sufficient value from CSIRO's long-term work has been a matter of debate, the resolution of which ultimately involved a shift to a required minimum level of non-appropriation funding (mostly from industry). However, as mentioned in Section 2.7.3, there are suggestions made that the proportion of 'national interest' research has now far less than the proportion of appropriation funding. Critics claim that this means CSIRO is using taxpayers' money to effectively subsidise their industrial customers, even when they charge nominally commercial rates. On the other hand, CSIRO points out that it can gain substantial benefits from such work, so what to some may appear a subsidy may alternatively be regarded as an investment.

In the case of both CSIRO and universities a strain has also been put on the attitudes to knowledge that they generate. This is now looked on as potential intellectual property, whereas previously it was seen more as a contribution to civilisation, to be published internationally. The strain has not yet been fully accommodated. Researchers and academics still regard publications as the most effective ways of demonstrating their credentials, and earning higher status and promotions. The reward system still reflects an earlier model of what the system is meant to do.

In any event, universities, but more especially CSIRO, are now more inclined to offer commercial rates on commercial terms. As far as the industrial customers are concerned this means transfer to them of all intellectual property rights and completion of the work in accordance with the customer's timetable, which usually has an element of commercial urgency.

An alternative is also available in which the charges are reduced in return for sharing of the intellectual property. As explained above, this means that both parties have to come to an agreement on the worth of this product, before it has been generated. This has often proved to be a thorny problem.

In addition to this point of contention, it has been the experience of many in industry that without the 'whip' of full commercial rates in the contract, researchers tend to work more to their own timetables. In fact, the complaint is that a culture of slower-paced work frequently ensnares even the fully commercial projects.

This is a particular problem for universities. Many university researchers have teaching responsibilities that must take precedence; this constrains their availability for research. Postgraduate (PhD and research Master's) students are available for research pretty well full time. However, they are apprentices in the 'trade'. Furthermore, the degrees that they are pursuing set requirements on the duration of the sustained piece of research that they must undertake, and the results must be publishable, as least within a short time. A good PhD student can be both cheap and excellent value, but there is no guarantee of this.

The cheapest way is through sponsoring a postgraduate research student. There can, however, be taxation implications for scholarships if the student is held to be effectively an employee of a sponsoring company. This means that very small sums of $10k, or so, are indeed scholarship top-ups, and confer no particularly favoured access to results. At the other end of the postgraduate scale, sums of $30k, getting close to a normal salary without the responsibilities of being an employer, may well be able to secure the exclusive services of a research student, supervised by a qualified academic. The down side of the deal has already been discussed.

Fundamentally, there are conflicts between the objectives of a PhD program and those who seek commercial advantage from the research that the student is undertaking. This will be considered briefly in Section 3.7.

In summary, there is a great variety in the types of 'research' available to industry. The costs differ, but so do the risks and the potential benefits. However, it is not quite as simple as being a case of 'you get what you pay for'. There are differences in objectives that must be understood and accepted by the customer who seeks to have research done for anything less than full commercial charges.

3.3.1 The value of money

It is quite notable that the same sum of money often, if not usually, has different values to the different players. A grant of $30k may be 'pin money' to a large company. However, it may be a year's funding to a PhD student. The same $30k may be leveraged to perhaps $100k by a university institute with internal university funding and Government support 'top-ups'. The significance also varies within a company. As has been remarked "it can be easier getting $50k than $5k". The level at which the approach is made within the company makes an obvious difference. At the same time, the sorts of problems that people are keen to have solved are generally different at different levels of management.

People in industry often seem to underestimate the value of discretionary funding inside a university. Referring to the allegedly inflated value that institutions may put on IP, they may point out the very few cases when large amounts have flowed

from royalties or the like (the IP relating to 'gene shears' is often mentioned). Even in such instances, they point out that the revenue is trifling in relation to the cost of running the university that owns the IP.

This may well be so, however, it isn't the criterion by which the sale of IP is judged inside a university. Getting commercial interest in a development may have great symbolic value even if no money flows from it. It is a sign that the research is considered 'relevant', and thus a powerful argument element in the politics of internal funding.

3.4 Research capabilities- growing a Research Centre

The simplest way of getting some types of research or testing done is to hire a consultant. Many academics are willing to take on short consultancies, subject to the priority of their teaching commitments. This is now regulated in most universities. The time allowed for consulting is commonly limited, and where universities have set up umbrella commercial arms (e.g., Uniquest Ltd in the University of Queensland) academics are encouraged to offer services through these

These arrangements are at full commercial rates, and any of the university's equipment and staff used in the work must be paid for. Any intellectual property is transferred to the purchaser of the services. Quite significant work can be done this way, but the restrictions on time limit its use in practice.

This example brings home a very significant characteristic of universities that is not always appreciated. Despite growing "corporatisation", universities retain a largely collegial structure. There are some duties that must be done (e.g., teach a certain number of courses), but it is hard for the university administration, or a Head of Department, to compel an academic to do anything specific. In some ways the academic is an individual entrepreneur within the institution. If the academic can obtain funding for a particular field of research (or operate without additional funding) it is hard for the university to do anything to influence the work. Influence in universities tends to flow more from earned authority than from formal authority.

The traditional test of appropriate academic behaviour has been whether the academic can establish and maintain a sufficient record of publication to gain an individual reputation and to bring kudos to the university. As funding gets tighter, this is changing to put greater emphasis on the ability to draw additional funds to the university, even if most of these are under the control of that academic. As is described below, there are cases where an individual academic entrepreneur has build up a personal research group that, in reputation funding and students, can rival the department in which it is formally located.

As with consultancy, the capacity of lone university academic researcher to do research is limited to the time left over after teaching and administrative commitments have exerted priority. It therefore varies throughout the academic year. The way to build up capacity usually starts by developing a stable of postgraduate students on scholarships, working on relatively inexpensive projects. These require supervision, but as they progress (and often from 'day one'), they are left to longer periods of work on their own.

The next stage is to hire Research Fellows (postdoctoral fellows), journeymen, rather than apprentices. This means winning a large enough project to support the new staff. This funding does not have to be for the three years needed to see a PhD student through to graduation. However, it has to be enough to pay a reasonable salary. The uncertainty of continued funding is, however, very disruptive for the Research Fellow, who may have to seek another position at the end of each year.

Assuming that the academic is set on growing the Group (and not all are), and that the funding keeps flowing, the group can grow into a recognisable Centre. The load can even come off the academic to some extent as the Research Fellows, who don't have such teaching responsibilities, take over the task of preparing research-funding proposals. Eventually the Centre is bringing in so much funding that the founding academic is progressively released from teaching and becomes a full time researcher and administrator of the Centre, usually within a Department. It's a hard road but it can be done.

A variation of this theme builds the Centre around a person appointed as a Research Fellow, rather than a teaching academic.

The JKMRC grew from this second starting point around Dr (later Professor) Alban Lynch. For over 30 years the JKMRC has always been almost 100% funded from sources outside the University of Queensland. Last year external funding amounted to more than 98%. The precise extent of the JKMRC's net contribution (positive or negative) to general university funds, taking into account the EFTSUs (see Appendix E) that it generates through postgrad uate teaching has long been a matter of some contention. This is, however, perhaps best described as an ongoing point of internal negotiation. That this is so suggests that net funding situation is indeed reasonably neutral in the greater scheme of things.

The JKMRC's name commemorates Dr Julius Kruttschnitt, who was the key figure in leading Mount Isa Mines through its inauspicious beginning to its emergence as a leading-edge mine in the 1950s. This is an appropriate reminder of the crucial role played by MIM Ltd in sponsoring the JKMRC through its early years. Mount Isa had supported Dr Lynch's early work, and had acted as a test site during the 1960s. After some seven years working in this mode it backed the JKMRC with funds for the first major building developments. Its continued

support of the Centre's research over many subsequent years provided much of the continuity of funding required to help it through the most critical years.

By the time a centre is up and running, it is able to take on both bigger projects and shorter projects. Bigger projects are possible because more staff are available, and the grants they have accumulated have built up the physical facilities. Small-scale pilot test work may be possible. They are able to handle shorter jobs because the senior research staff are not limited by teaching, and can give faster response. At this stage a consulting arm makes sense; again the JKMRC is the archetypical example in the field. In the JKMRC this arm (JKTech) markets hardware and software developed to commercial standard. This has proved to be a very powerful for delivering and applying research outcomes in a useful way.

A continuing supply of able PhD students can form the backbone of the research team. There is now a sequence of these coming through with varying degrees of proficiency. In the case of the JKMRC some protection is afforded the students by ensuring that the research projects, many funded through AMIRA, are long term, and constructed around themes (as with "AMIRA P9"). It is possible for a student to contribute to a succession of different projects while completing an integrated and sustained piece of research to form the basis of a thesis.

In full operation after over 30 years of organic growth from its origin in one person, the JKMRC is a most impressive accomplishment. As well as contributing to the research and supervision, the senior roles now includes a large administration component and constant recruitment as PhD students and postdoctoral fellows move through the Centre. However, the constant task is seeking funds.

The JKMRC is very much a commercial operation, and its use of PhD students in its research is a key feature of its economics. A balance has to be struck between the low remuneration of the students and their low productivity in early stages of their postgraduate education. In fact, the JKMRC has now established a ratio of student to research staff that is considerably lower than it had been for most of its history.

Students have been known to complain of exploitation. However, on the rare occasions when this has occurred it has been early in their tenure before they have understood the model that supports their studies. Nevertheless the potential for conflict has to be carefully managed. This said, they get good money by scholarships standard, and exceptional exposure to the industry, as most projects have a significant component of on-site work in the sponsors' operations.

3.4.1 Growing pains

There is always some tension between the university's goals of increasing knowledge, and its mission to transmit the knowledge - balancing the needs of research and of teaching. It always is handled on a case-by-case basis. Thus it has become a defining myth within the JKMRC that "this place would never had got to where it is today if it hadn't started in a tin shed off the University campus". This is certainly one way of avoiding the tension.

The JKMRC model has proved to be an effective one within the minerals industry, but it may not necessarily work so well in other sectors and industries. However, there are other ways a Centre can be formed. For example, in Curtin University of Technology a Centre for Exploration Seismology has been grown out of a small department - Exploration Geophysics. The Centre for Strategic Mineral Deposits has formed within the larger Department of Geology at the University of Western Australia. As discussed elsewhere in the context of teaching (Sections 4.5.3 and 4.5.4), neither situation is entirely comfortable. The price that the JKMRC has paid in return for avoiding battles over funding from EFTSUs is to run almost entirely on external funding. However, as noted above, this continues to be an issue in relations between the Centre and other parts of the university. The Centre certainly has an interest in the state of undergraduate teaching, partly because it is a local supply of postgraduate students, but faced with its own funding needs charges commercial rates for any undergraduate teaching that its staff provide. The JKMRC has always had a large proportion of postgraduates from other universities and from overseas, but recruitment and some other costs tend to be lower with locals.

3.4.2 Establishing a presence - a window to the World

At a certain senior level the industry would much prefer to have a simple interface with complex bodies such as universities. Closer to the operational level, people in industry object to having 'non-value-adding barriers between the industry and the people who will do the research for them.

To emphasise this point, the reactions of the JKMRC to suggestions that it "should establish a presence in Western Australia" are worth considering. On the surface it makes sense; 35% of the JKMRC's funding comes from industry operations in Western Australia. However, the JKMRC itself maintains that it would be counter-productive to set up a mere 'shop-front'. If it were to come to Western Australia it would have to be at a level that would allow work to be carried out in this State by people based here.

With this qualification, most 'centres' take steps to develop an internally unified, but differentiated image. For example, the JKMRC has always placed great store in presenting a 'professional' interface to potential funders. Its reception area has never resembled the 'keep the students out' style of the conventional

university departmental office. Since it is also 'off-campus' it is easy to achieve the differentiation.

The same tendency can be seen in other centres, such as that for the Centre for Exploration Seismology at Curtin University.

Another way of presenting a distinctive window to the world is demonstrated by the brochure produced by nine Centres, one Group and one Department within UWA. These are essentially separate units at various stages of development into independent research centres (in terms of the descriptions above), attracting in total around $2 million annually in industry funding in the resources area. They have combined their presentations to the industry under the brochure's heading of "Excellence in Research and Education for the Mining Oil and Gas Industries". However, although they have this shared public face, Industry approaches them separately, and they compete against one another for research funding.

The next stage is to formalise the interface to some extent. At Curtin a Faculty of Minerals and Energy will emerge from a reorganisation. At UWA a program in Resource Engineering is being planned (Section 4.4.3). Undergraduate courses in this program will draw on existing engineering subjects, complemented with additional curriculum material rather than being established from scratch. The term "School of Resource Engineering" has had some circulation in connection with this program, however in the short term it will be managed by the Faculty of Engineering and Mathematical Sciences.

At the University of Queensland the Sir James Foots Institute of Mineral Resources has a formal interface role as a point of contact between the university and industry. The Foots Institute will speak for the University on certain matters related to the minerals industry and will "take official carriage" of them. It is not seen as coordinating activities in this field within the university (too hard a task, given the realities of the system). Rather its task is to spot new opportunities for the university in this area. It takes a keen interest in perceptions of the strengths and weaknesses in teaching in the University's related discipline areas, but has no academic management function within it. It is not so much concerned with research *per se***, as it is with the "totality of post-graduation education and training, particularly distance education for continuing professional development.**

The other main way of developing an independent presence is through forming a Cooperative Research Centre, discussed below.

3.5 COOPERATIVE RESEARCH CENTRES

About seven years ago the Federal Government of the day reallocated research funding to sponsor the development of Cooperative Research Centres (CRCs). The idea was to provide partial funding for a period of seven years to enable research groups and centres to combine their efforts and so achieve ‘critical mass’ and better use of facilities and expertise. The emphasis has always been on getting industry support and involvement, and the intention was that CRCs should become self-funding. There has been a series of funding rounds in which new CRCs have been started.

The recent Mortimer Report takes a very critical view of the CRC program and recommends reducing funding from $140 million per year to $20 million per year for five years. This aspect of the report has prompted very strong dissent, including a response from Chief Scientist John Stocker. The Mortimer position appears to be based on the view that the CRC program is a business incentive program and that public funds are being inappropriately used to benefit the private companies that participate in them. On the other hand, defenders maintain vehemently that the CRC program is a model for the rest of world as to how research infrastructure should be built up and used effectively.

The debate as to the purpose of the CRC program will be conducted elsewhere, but for the present it is sufficient to note that there is considerable controversy about its success to date, and the differences arise from differing expectations of what the program is meant to achieve, and how they are meant to operate. Indeed, people who are involved in more than one CRC report that flexibility is one of the strengths of the program. Different styles of Centres operating in a range of different ways can be set up to meet the needs of particular industry segments.

One thing, however, is clear: the vision of independent viability has not been been matched by reality. It seems that none of the CRCs has actually attained this state. Some have separated into their original components once the glue of Federal funding had run out. A few others have been reconstituted to have a second shorter term, with somewhat different objectives. A range of degrees of success is to have been expected, and it is generally held that some CRCs have been more serious about seeking continued viability than have others. The CRCs also demonstrate markedly varying degrees of cooperation between the partners.

The minimal mode of operation appears to be, in effect, that the partners use the funds as an additional resource, to be split between themselves according to some formula, which they use to pursue in much the same way as they would have been doing otherwise. This leads to the Mortimer criticism. The ideal is represented by the situation where a strong management allocates funds and resources on the basis of the merit of research proposals. Generally, the partners maintain their own separate existence while participating in a CRC; it is not a merger.

There have clearly been tensions when one of the partner research groups in a CRC sees an opportunity for research funding. Does it take the work in its own right, or put it through the CRC? This can be headache for a Director of a CRC. Another problem is presented when one of the partners retains intellectual property rights derived (though not necessarily directly) from a CRC project. This is somewhat like the situation in which companies leverage value from collaborative AMIRA projects. In such a case the CRC is more like 'Collaborative' Research Centre than a 'Cooperative' one.

The network of memberships of CRCs is complex. It is common for research groups to participate in more than one at the same time. The industry, through AMIRA, has been part of six CRCs, and in addition, individual companies have also been partners, while they are also members of AMIRA. The Department of Exploration Geophysics at Curtin is a participant in three, as a member of the Australian Petroleum CRC (APCRC), and the Australian Mineral Exploration Technology CRC (AMET), and a supporting member of the Centre for Mining Technology and Equipment (CMTE-2, the "2" signifying the second stage of funding).

CRCs have been an effective way of establishing the sought-after independent standing. The A J Parker CRC for Hydrometallurgy (Murdoch, Curtin, Western Australian Department of Minerals and Energy, and AMIRA) has certainly had an impact in its five-year history. It also seems to have overcome the challenges establishing identity while operating on two sites. Possibly the reason is that the two sites are only 20 minutes apart. However, the evidence suggests that it is the quality of relationships that really counts.

Expanding on this, the A J Parker CRC is only formally a partnership between institutions. It really works because it is a partnership between certain people in Murdoch's School of Physical Sciences, Engineering and Technology, Curtin's Division of Engineering and Applied Science, CSIRO Division of Minerals (Waterford Laboratory), the State Mineral Processing Laboratory (and Chemistry Centre), and in AMIRA.

As a final comment, it is not clear that CRCs have significantly increased the total amount of mineral industry funding of research. Some companies appear to have redistributed their external funding to direct a greater proportion to CRCs, without increasing the total. Moreover, another strain on resources arises because each of these organisations requires boards of management and technical advisory committees. However, the pool of available expertise is limited and the degree of interconnection and overlap between the people involved is already quite striking.

3.5.1 Commercial operations

The ultimate accolade for a research centre or CRC may well be to spin off an independent commercial operation. This has happened with some CRCs. The JKTech operation, although formally a trading arm of the University of Queensland's Uniquest Ltd, has a turnover of about $2.5 million. There have been some bigger businesses arising in the telecommunications area, but not in the minerals and energy field, as yet. The disproportionate symbolic value of commercial success within the university system has already been discussed.

3.6 GETTING WORK

Getting funded research work is a competitive business. For the lone researcher, setting out to establish a reputation, the Australian Research Council (ARC) grants are a common starting point. These are awarded on the basis of peer review, and are available in several categories. Some years ago, with the number of applicants growing faster than the supply of funds, the average award amount had been falling to figures that many felt were too small (as low as $10k) to be justify the considerable expense and effort of making the application. This prompted the move to the current system where ARC Large Grants, won in open competition, now average around $50k, but in which the overall success rates for applicants is now only about 20%. This is an average figure; the ARC targets particular areas of research from time to time - some have been in the minerals area. Small Grants, typically around $10k - $15k, are still available from ARC funds, but competition for these now takes place within individual universities. They are usually intended as seed funds to develop projects that can attract ARC Large Grants or other external support.

The real, but hidden, cost of the selection process must be enormous. Preparing an application is a major undertaking (it takes days rather than hours). The peer review system is also very demanding on expensive time. Certainly some qualified research people in industry choose to decline the honour of being a reviewer. Unless there is an appropriate targeted research to compete for, academics who have alternate possible funding sources (such as industry) are being advised by their mentors to avoid ARC. However, it is different if there is a chance for a targeted large grant; the Western Australian School of Mines has recently had considerable success with this route.

Universities normally maintain a research secretariat that keeps staff informed of opportunities to apply for funds. The importance of research grants in funding formulas has already been mentioned. They also figure in determining a university's 'profile', and this too has ramifications for recurrent funding.

All the above difficulties tend to make industry funding attractive. The balancing factor is that the industry tends to regard itself as a 'customer', with the degree of interest increasing almost exponentially with the amount of money concerned.

This can be a real nuisance for a researcher who would really just like some money to pursue personal interests! It may also mean placing some sort of restriction on publishing the results, and this is a problem because it is the main way of building an academic or research reputation.

As project managers, as well as brokers, AMIRA and MERIWA can figure in two ways in this situation, being a buffer between the researcher and industry. They can protect the researcher from unreasonable demands, but they can also be seen as hindering the development of personal relationships, by which the researcher can more easily generate future projects. How they are seen depends on the researcher's ambitions.

AMIRA funding depends very much on the capacity of AMIRA's own staff to know the research scene. They often make specific suggestions to industry as to which research groups are in a position to do certain work. They act as brokers, gaining a feel for what the industry research needs industry would be likely to fund, inviting research groups to write proposals around these. They then, in an iterative process, send these back to industry to be massaged into a form acceptable to all the sponsors and to the researcher.

Any researcher wanting work through AMIRA is well advised to form a close relationship with the relevant AMIRA staffer. By the same token, there are complaints that lack of AMIRA staff expertise in certain areas means that they may be unaware of opportunities on both sides.

Building personal relationships is the key to successful fund hunting. The JKMRC's travel bill for 1996 was $400k (with an additional $200k for JKTech, its consulting arm). Some CSIRO Divisions have been similarly active, and some are arranging formal relationships with companies. There is some concern that these are considered likely to have the effect of squeezing other researchers out. The CMTE (CRC) has succeeded in getting work out of reluctant sponsors by maintaining such a presence that its staff have come to recognise improvement opportunities in industry before the operating companies have.

Many CRCs and Key Centres (another special initiative) are grappling with ways to achieve viability before funding runs out. One of the interesting methods being used by several including the UWA Centre for Strategic Mineral Deposits, is a system of annual 'memberships' at various levels; some use terms like 'diamond', 'platinum', and 'gold' levels of sponsorship, typically at around $5k per year. This entitles member companies access to seminars, rate reductions on special short course, etc. It is all aimed at building on-going relationships.

This may be an unwelcome message for a lone university academic with teaching commitments and an ambition for an independent research career. There is clearly pressure to join an established research group. This had always been part of the idea behind CRCs, on the grounds that it would avoid further dissipation of effort, and help achieve that elusive 'critical mass'.

Chasing research is increasingly competitive. The Federal Government is decreasing funding, particularly to CSIRO. The university system continues to grow, and industry is looking increasingly critically at its research spending. A PhD does not seem to be quite as attractive as it once was as a 'meal ticket', but with general 'qualification inflation' it is still required for entry to some careers, so there is still a demand for research projects for students to work on. This will be discussed in the next section.

3.7 LONG-TERM RESEARCH AND THEPHD SYSTEM

The increasing trend towards shorter-term funding from industry, with greater competition for ARC funds, and the increasing CSIRO focus on work for industry, raises the question of "where is the funding for long-term work going to come from?" This recalls the argument behind the 'vicious circle' sketched above in Section 3.3. "Without long term research we will not be replacing our intellectual capital."

This is certainly arguable, but others reject it as just "the standard whinge". Some, who take a particularly detached view have suggested that focus on science has been in an unsustainable growth cycle, at the expense of other branches of culture, and the limits are now being reached. Others who don't subscribe to this, simply say the need for 'long-term' or fundamental research is overstated. These are the people who point out that only perhaps one in ten PhDs will go on to become an independently creative researcher. The rest will have received a good training in scientific method and self-management and thereby become superior employees, and even business people.

The premise of the traditional PhD program is that it should be based on a original contribution to knowledge achieved through a sustained program of research spanning at least three years. This would seem to require that funding for at least this length of time is essential to support a PhD project. However, the critical factor is confidence that funding will somehow be forthcoming. The JKMRC has produced dozens of PhDs while working on annual funding. This has, of course been aided by the long-term succession of sub-projects within some AMIRA umbrella projects. The students have met the traditional criteria for their theses, but some of them have achieved this through work on a succession of related research projects.

This raises some questions for the future. How related do the research topics in the set have to be to constitute a sustained research program? What sort of graduate would three separate one-year projects of increasing complexity

produce? Perhaps the PhD will stay as it is and another award can be introduced. A study by the higher Education Research Council in the UK has led to a number of new doctoral programs in Engineering in that country. In this regard Deakin University is now advertising a doctoral level engineering degree to cater for people who are not intending to embark on a career of fundamental research. It will be interesting to see how much appeal this has to its customers among the graduate ranks. It may be easier to marry this model to shorter-term industry funding.

4 THE CURRENT EDUCATION AND TRAINING SYSTEM

This chapter deals with the suppliers of trained people into the minerals and energy industry. Much of the recent discussion on this topic has centred on the university system, so this sector receives most attention. However, this chapter also shines some light on what is happening in the Technical and Further Education (TAFE) arena.

1. The chapter starts with an overview of the State's universities and their funding. These financial realities have tended to discourage the universities from adopting some of the ideas for change that the industry has suggested. This is taken up in the next two sections.

2. Thus the second section expands on the industry view of the university system. This draws on the Discussion Paper published by the Education Taskforce of the Chamber of Minerals and Energy of Western Australia in 1996. It does not, however, accept everything in this paper at face value.

3. The third section examines the view from the other side: how those in the universities see their role. This reveals an important cause of misunderstanding. The industry thinks that it is the customer for the universities' services. However, as far as the universities are concerned the student, not the industry, is the customer. The Chamber's vision of a rationalised system runs up agaist the reality that:

   > ... the present regime of funding tertiary education works by competition for student enrolments. Under such conditions no institution is inclined voluntarily to withdraw from offering courses that students might find attractive

   The section goes on to say a little about how the different universities are going about the business of attracting students.

4. Following the publication of the Chamber's discussion paper a succession of events has led to the establishment of a committee to progress the formation of the 'Western Node' of a proposed National Centre of Excellence in Teaching and Research in Minerals and Petroleum. The fourth section describes current moves in the Western Australian university sector in relation to this development.

5. Many of the problems that occur between the industry and the education sector are tied up in the dynamics of recruitment. It takes a considerable time to train someone for the industry, but the industry is notoriously cyclic

and graduate supply and demand are frequently out of step. The section goes on to consider the consequences and possible remedies

6. The TAFE sector is covered in the sixth section. This sector seems poorly understood, and may be under-valued, by the minerals and energy industry, possibly because the system is quite complicated and in a process of change that has not yet entirely stabilised. The implications of the changes to funding and the move to competency-based training are only now beginning to become apparent to industry, and concerns are emerging about training at supervisory level.

7. The seventh section refers to prospects for growing the education industry.

8. The final section touches briefly on continuing professional development and distance education.

4.1 WESTERN AUSTRALIA'S UNIVERSITIES

In order to make sense of the discussions of the various views and moves in university education for the minerals and energy industry it is first necessary to get some grasp of how the system works. This section presents a snapshot of the current university system and its funding.

For the period between 1965 and 1988 a two-tier system of Universities and Colleges of Advanced Education (CAEs), some called Institutions of Technology, was maintained. This distinction disappeared in 1988 when the 'Dawkins White Paper' established the Unified National System. None the less, inequalities in facilities and reputations remain.

The University of Western Australia is the State's oldest, and claims the distinction of consistently attracting the highest proportion of the students who gain the highest Tertiary Entrance scores in high school examinations. As well as being strong in sciences, UWA has a highly regarded engineering faculty. The undergraduate engineering courses tend towards principles rather than the vocational aspects of the educational balance, and do not have much history of close linkage with the minerals and energy industry. The recent establishment of the Woodside Chair in Offshore Engineering is one of the more visible signs of its intention to move more directly into the Resources area.

Curtin University of Technology has grown from the Western Australian Institute of Technology, which in turn was a development of the Perth Technical College. In addition to departments teaching various branches of geology in its Faculty of Science, it has the State's only department of Chemical Engineering in its

Faculty of Engineering at the Bentley Campus. It is the first choice for the largest number of students seeking university entrance.

Curtin incorporates the Western Australian School of Mines (WASM), as part of its Kalgoorlie Campus. The School of Mines was founded under the control of the State Department of Mines in 1902 (ten years prior to the establishment of the University of Western Australia). Over the past 28 years, however, it has been part of Curtin and has shared in its development to university status. Curtin University Kalgoorlie is itself a merger of the School of Mines and the Kalgoorlie College of TAFE (Technical and Further Education, see Section 4.6) and as such offers a prime opportunity for linkages between university and TAFE educational offerings in mining education.

The Curtin School of Mines is the only institution in Western Australia offering a degree in Mining Engineering. It also offers the State's only degrees in Minerals Engineering (extractive metallurgy), and the BE in Mining Geology. Its total graduating class in 1996 was 81, which is said to make it the largest mining and minerals school in the world at this time. The exposure of the graduates to the industry during the course is claimed to give them the equivalent of about one year's experience at the time they graduate. With this potential to be immediately productive, combined with their university level foundation for continuing professional development, graduates have proved attractive in the job market.

Murdoch University was one of the last-established 'traditional' universities, being designed and funded for research and teaching. It has a well-regarded Minerals Science program centred on hydrometallurgy, and is just about to launch a School of Engineering on a campus shared with Rockingham College of TAFE (Technical and Further Education).

The multi-campus Edith Cowan University was formed from a College of Advanced Education. This had in turn been formed by incorporating a number of institutions, including several Teachers' Colleges. It has set up engineering courses in the field of electronics, but does not yet figure notably in discussions of teaching that is oriented particularly to the minerals and energy industry. The same remark can be made of the University of Notre Dame Australia, the State's newest, and only private, university.

Western Australian has a State Office of Higher Education, which in the present context has two major functions. One function is to provide administrative support and policy input to the Western Australian Higher Education Council (WAHEC), which is a Committee made up of the five Vice-Chancellors and the Director of the Office. This Council provides advice to the Minister of Education, as required, and acts as a mechanism to promote cooperation between universities, to address common issues, and to promote higher education generally. The universities are, however, independent Commonwealth-funded entities, and even though they are created under State legislation and are

responsible to State Parliament the system is not 'coordinated' as such at the State level.

In its other major role, the Office of Higher Education is responsible to the Minister for State higher education matters and undertakes Commonwealth/State negotiations and the promotion of higher education from a State perspective.

4.1.1 A brief history of university funding

In the period of little more than a generation a university education has changed from being something for the elite - either by virtue of wealth or having the intellect to gain a scholarship - to a commodity. In the 1950s it has been said "more Australians had spent time in a mental asylum than had been to university"; now more than 20% of the youth age cohort undertake tertiary education studies. Indeed the proportion of the entire working age (17 to 65) cohort undertaking university studies is now around 5%, up from about 3.5% ten years ago.

The consequent great increase in the call on the public purse has led successive Federal Governments to seek ways of increasing the 'efficiency' of the system. This is, however, a rather nebulous term because there is a notable lack of agreement on what the goals of the system are. Nevertheless, attention is being increasingly focussed on the current methods of funding, which are based on profile (course and discipline mix) and student targets (at undergraduate and postgraduate levels) set by the Commonwealth Department of Employment Education and Youth Affairs (DEETYA). It is argued that greater competition between universities, and less central control, will be an essential component in future funding models.

Universities are established under State law, but in 1974 the Federal Government assumed full responsibility for funding the public universities. Prior to 1974 student fees made up about 20% of university funding with State and Commonwealth making up the rest in roughly equal proportions. For the period from 1974 to the last part of the 1980s university education was free to students, but fees are now imposed through the Higher Education Contribution Scheme (HECS), which is described below.

As part of the moves to reduce public expenditure Australian students whose school performance allows them to earn a place in the quota for a particular course are ultimately charged a fee (the Higher Education Contribution Scheme, or HECS, charge). The HECS charge varies with the particular category of course, with the charge for engineering being higher than that for, say, Arts. Even so, the charge is less than 20% of the total course cost in expensive areas like

Chemical Engineering, while it is more than 20% in relatively cheap areas such as Law.

Students may pay the HECS charge 'up-front' at a discount, or may choose to defer paying the fees, in which case it will be collected later out income tax when their income after graduation exceeds a certain threshold. Overseas students can be accepted on payment of the full course fee, directly to the university. This option is being extended to Australian students who do not qualify for a quota place.

In one sense the HECS system is a return to the pre-1974 system in which students paid fees of around 20%. However, scholarships were much more readily available in those days. They were more plentiful in absolute numbers, and because a far smaller proportion of young people sought university places, the proportion of students with scholarships was disproportionately even higher. There is relatively little assistance available through the scholarship mechanism these days, although actually the minerals and energy field is better placed in this regard than most other areas of study.

The options provided by the Federal Government to assist student access to universities are, moreover, being steadily reduced. Eligibility for the Austudy program is increasingly difficult. A condition for eligibility for independent-living assistance (i.e. so-called 'living away from home allowance') is that the student has to be over 25 years of age.

Within the university system funding is not directly related to the cost of teaching particular courses. Instead it is provided on the basis of student numbers and an average cost per student determined from the university's profile. This takes into account the fact that some courses, particularly those with a laboratory component, such as engineering, are relatively expensive. There are quotas on student intake and provision for competitive bidding between universities for additional student places.

The result, however the funding is determined and sourced, is that there has been a significant real reduction in funding per student over the last decade. Some suggest that the fall has been as high as 20% per student in some areas. It is less than this on average, but figures are hard to quantify for several reasons. Firstly much of the growth in enrolments has been in relatively cheaper areas such as Business and Law, etc, and this has cushioned the blows to some extent. The other complication is that recurrent costs don't tell the whole story. Some of the worst effects of funding reductions are hidden as deferred capital developments, reduced maintenance, and slippage in the quality of equipment, etc.

Internally the universities use various methods for distributing funds to the teaching faculties and departments. However, in the end these mostly reduce to

a set sum per 'equivalent full time student unit' (EFTSU). Ensuring that sufficiently high EFTSUs are earned by enrolments in a course or department therefore becomes a preoccupation of those within the system.

The harsh reality of decreasing real funding, combined with an increasingly competitive framework, is exerting a continually increasing pressure on the higher education system, the effects of which are evident in the developments discussed below.

4.1.2 In summary

University education is no longer free to students, although fees may be deferred. There are few scholarships, and little assistance with living costs. Australian universities are not well provided with cheap accommodation for students, and most students live with parents, at least for the first years of their courses. Indeed, most remain dependent on parents throughout. Students in non-metropolitan areas have access to the Bunbury Campus of Edith Cowan University, and external studies in a range of courses, supported by study centres and visiting tutors. Nevertheless, for Western Australian students from outside Perth a university education in many subject areas remains a major expense that families have to plan for.

Universities are funded on the basis of student numbers, with an element of competition taking place between institutions for a pool of student places. Funding on the basis of student numbers usually extends down to department level. Full-fee-paying students, at this stage predominantly from other countries, represent a major growth area for universities, and a way in which they can escape some of the pressures resulting from increasingly tight Federal Government funding policies. Overseas students are also attractive to State and local governments because their costs of living provide a boost to the economy. The political backlash, on the grounds that they displace Australian students, has been addressed in part by extending the fee-paying option to local residents.

4.2 THE INDUSTRY POSITION ON EDUCATION

People are important to the success of any business, but shareholders in a minerals or energy company (in the producer category) would worry if it seriously claimed that its operating people were its greatest asset. On the other hand, its resource evaluation people may well be critical to its success, but this is because the fortunes of such businesses are largely determined by their geological resources. Indeed, the position of the industry appears to be that access to operational staff is a non-competitive aspect of their operations, something like environmental compliance. This, one may suspect, is the reason that the

Chamber of Minerals and Energy of Western Australia was able to endorse the discussion paper published up by its tertiary education task force in July 1996.

It is widely agreed that this publication gives a very good description of the situation with respect to university graduates, in Western Australia at least. Its recommendations have, however, raised some hackles, especially from educational institutions, and from other States. The immediate criticism has been that the paper's recommendations came across as being focussed on Western Australia, when the industry, and the suppliers of trained people to it, has an Australia-wide scope. The scope is in fact global, but as discussed below, the global scene is no better, and there is tacit agreement that getting an Australian solution will be a sufficient challenge.

The paper has undoubtedly stimulated debate on what all acknowledge is a very important issue, and this has spurred further action. The Minerals Council of Australia is now preparing a similar paper, this time with a specifically national focus. This is being chaired by Mr R J Carter, who was also chairman of the taskforce that produced the Western Australian paper.

The Western Australian Chamber's paper makes only passing mention of skilled technicians and para-professionals. The education of these people is taken up in Section 4.6.

At the heart of the recommendations is the proposition that the industry should exert greater control over courses through some sort of coordinating and accrediting body. This would exert a strong influence over, if not actually dictate, which courses should lead to accepted qualifications. In order to support this, the industry is asked to commit to a program to attract people to train, or re-train for the industry.

The tertiary education providers, and others, have their doubts about this. First, educators are not generally attracted by the prospect of losing any of their autonomy. The notion of autonomy runs very deep within universities. Indeed, academic leadership of the discipline areas is normally so strongly a professor's preserve that a university will usually find it easier to exercise control through the blunt instrument of funding rather than to try to interfere directly with the academic content of a particular course.

Moreover, the present regime of funding tertiary education works by competition for student enrolments. Under such conditions no institution is inclined voluntarily to withdraw from offering courses that students might find attractive. If the industry is expressing concern about a shortage of graduates it may not appear to a university to be the best time to close off to its potential students entry paths to a potentially attractive career in the minerals and energy industry.

Besides which, the education institutions have come to doubt the ability of the industry to deliver on pronouncements that it makes about its training needs.

As the following overview reveals, the need is for a multi-level system of training and education. Whether or not this is best provided by the sort of coordinating, or standard-setting, body that seems to be envisaged in the Chamber's task force remains open to question.

The Chamber's report refers to the professional bodies; their role was considered in Section 2.8.2. However, it should be noted that with some exceptions, such as Mine Manager, where certification is mandatory, there are few restrictions on joining the industry. Neither is it generally necessary to be a member of any professional body. In practice, as far as the industry is concerned a metallurgist (say) is a job description, rather than professional title. If people prove that they can do the job of a metallurgist, then that is what they are. This is significant in dealing with the industry's cyclical demand.

4.2.1 An overview of education for the industry

For a long time the industry operated on a two-tier system in the employment of professional staff. Big companies have employed the new graduates, and given them their initial industry skill formation. Smaller companies, claiming that they are unable to afford these less productive years, have preferred to recruit experienced staff. Large companies have paid lower salaries for less productive people, and smaller companies have paid a premium for experienced staff. Thus, although the employers of new graduates have always complained about this, there has been a balance of some kind.

In preparing the discussion paper the Chamber of Minerals and Energy task force surveyed "55 senior managers of mining, exploration and processing companies". The paper highlighted a finding that only 16% of respondents to their survey recruited new graduates. This indeed seems an alarmingly low figure, but it may give a distorted view of the situation on the ground. It certainly appears to conflict with advice that there was high demand for the historically large number of 35 graduates in Mining Engineering from the Western Australian School of Mines last year. Many, if not most, of these are said to have been employed in small operations where there may only be one more senior mining engineer on site. Perhaps these companies were not surveyed.

Whatever the exact current situation, times are changing. In the past, large companies offered structured career development paths and greater security. In return, staff had been willing to accept somewhat lower salaries. These days job security is a thing of the past, and more of the experienced staff are prepared to move to smaller companies offering higher salaries. The dynamics that maintained the former steady state are changing.

On top of this there is a worldwide decline in the production of graduates for the industry. Former centres of education, such as the Royal School of Mines in London, are in decline or closing.

The effort put by senior representatives of the industry into the preparation of the two task force studies indicates the concern that the industry now feels about the shortage of suitable recruits.

4.2.2 The view from the universities

Those engaged in education recall that history has not painted the industry's involvement with education in an entirely flattering light. In Australia prior to the removal of university fees in 1973 a smaller proportion of the population had aspirations to a university education, there was a well-developed scholarship program, and there was also a tacit understanding that the large companies would employ a certain number of graduates each year. This they tended to do, thus dampening down the effects on student numbers of the notoriously cyclic minerals economy. This broke down almost immediately when fees were abolished. Graduates became almost a 'free good' as far as industry was concerned.

This had a destabilising effect on specialist departments in universities. In the new regime the fact that a graduate had studied specifically what the industry had said that it required counted little with employers when the minerals economy was down. On the other hand, when the economy was in a boom the industry would take graduates from generalist courses such as chemistry, or from other branches of engineering. Thus, universities learnt to be rather sceptical of the industry's advice on what it wants in its recruits.

The present competitive situation in higher education means that attracting students is even more critical to universities. Furthermore, now that students have to pay the HECS charge for their studies there is a clearer economic choice facing students in their course decisions. Institutions see it as a competitive advantage to be able to offer courses that allow students to delay their commitment to such a specific and cyclic industry as Minerals and Energy. This allows them to judge better what their prospects of employment are likely to be.

Thus, universities see the industry, when it is going well, as attractive to students, and do not wish to be excluded from the opportunity of supplying it. On the other hand, history has shown that trusting the industry too much, and devoting resources to develop the specialised courses that the industry has said it wants, can harm university departments. Reaching a resolution to this dilemma will be a challenge.

4.2.3 Different needs within the industry

The task force discussion paper is clearly one that the executive, if not every member company, of the Chamber of Minerals and Energy of Western Australia can endorse. However, this means that it encompasses a wide range of needs.

For example, the paper outlines a composite set of ideal attributes and skills for a new entrant to the industry. This has been dismissed by some as a desire for "a 21-year-old new graduate with ten year's experience".

In fact, this is by no means what every company wants. The smaller operating companies do want someone who can be usefully productive in the field as quickly as possible. However, this is not the case with others, presumably drawn from those of the 16% who reportedly recruit new graduates.

These are really interested in recruiting their pool of future senior executives. They want the brightest and best who have "a sound base in science and mathematics, have been taught to think, and have sufficient personal and industry-specific 'survival skills'; the factual details can be learnt later". A similar thought was expressed quite bluntly: "we want UWA to get involved because that's where the best students go." This might not be fair, but it's what the other institutions are up against.

The Chamber's report also appears to be biased towards the minerals industry. The leading companies in Petroleum have long made a practice of recruiting the very best graduates in any engineering field, regardless of specialisation. Recruiting visits by, e.g., Esso and Schlumberger create considerable excitement among the top students. In this regard they are like the minority of Minerals companies just described. At both senior and at operator level the petroleum industry has been more prepared than the minerals side to undertake its own specialised in-house training.

4.2.4 Education and research

The competitive leverage provided by research makes it virtually impossible for the industry to make more than rather general pronouncements on this topic. At the same time it recognises that the good teachers required to advance its educational aims will have to be provided, at university level, with opportunities to do research.

So, essentially, the industry would like to divorce the discussion of education (on which it can achieve internal consensus) as far as possible from any consideration of research (on which its member companies cannot agree).

Although nobody has actually said this, it appears that the industry's position can be expressed in the following way. "We might be prepared to support a bit of research for the sake of holding good educators, but any useful results from this research would just be a bonus and we wouldn't take them into account in costing our involvement."

According to this, research is part of the cost of education, although it might throw up some benefits. One would however, expect a more active debate within the industry if any benefits of the research were seen to accrue to one company or sector rather than to the industry as a whole.

4.2.5 Maintaining relationships

The Chamber's discussion paper expresses concern about the way that limited teaching resources are spread too thinly, with the relatively small number of students required by the industry being taught in a large number of small departments. The paper states that this makes it difficult to sustain consistent industry input. It is also seen to "compromise the identity of dedicated minerals industry related programs", as small departments are merged into larger generic ones. This also makes it difficult "for universities and industry to develop and maintain effective relationships".

There is no question that the industry would like a simpler interface with the suppliers of its future workforce. Indeed, this theme is repeated in the industry's views on the TAFE area.

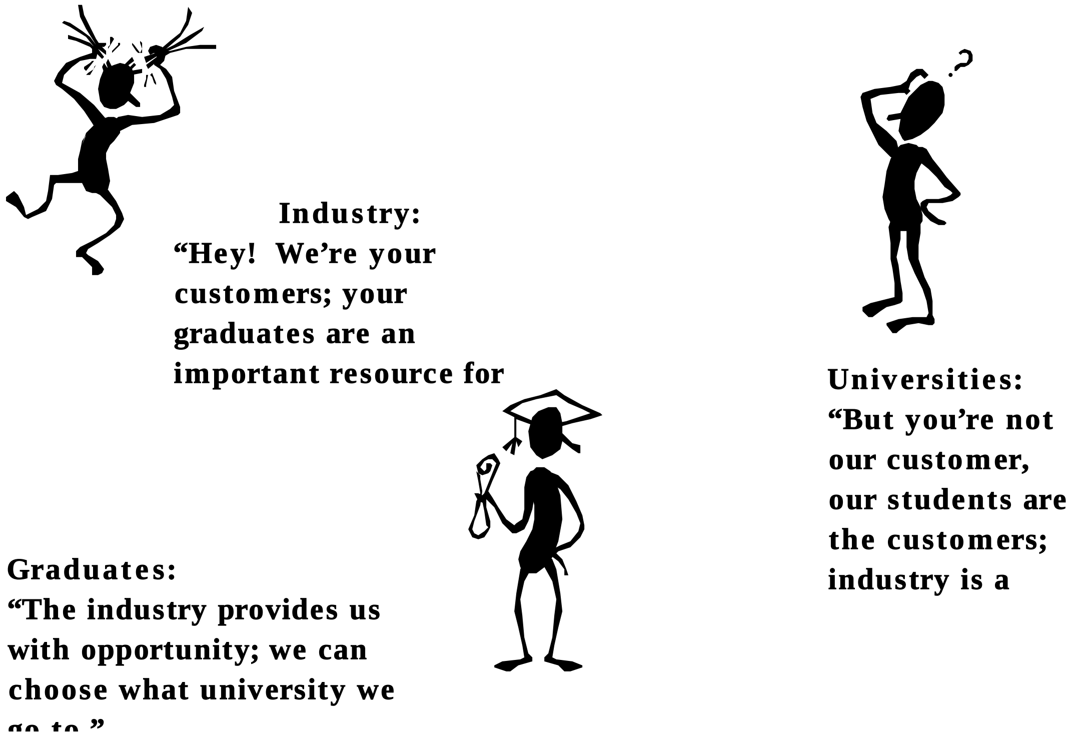
Whilst some on the education side would see this as motivated by the industry's self-interest, the need for critical mass makes good sense. It is exactly the argument raised in considering what it takes to establish a reputation for excellence as a technology provider (Section 2.5). The observation that the behaviour in universities has taken them in quite the opposite direction requires some analysis before it becomes comprehensible. This is taken up in Sections 4.1 and 4.4.

4.3 THE TERTIARY EDUCATORS' VIEW OF THEIR ROLE

The industry's view of the educators includes the observation that they have notably failed to grasp the nettle of amalgamating facilities to achieve the critical mass needed for excellence in serving the needs of industry. After all, competition has ensured that critical mass and excellence are keys to the continuing success of the leading providers of technological expertise to the industry. Why doesn't this apply to university teaching?

The answer to why this should be so appears to lie in the non-reciprocal nature of the relationship between educators and the industry.

Universities and the industry are not in a mutual supplier-customer relationship. The factor that intervenes is the student, as in the following cartoon:



Non-reciprocal relationships

The cartoon overstates the case in order to make the point; certainly, few students would say that they have felt like customers at university! And the more vocationally oriented departments within universities have always been dependent on the state of recruitment into the industry for their student numbers. However, it seems fair to say that, until recently, universities haven’t been very conscious of the notion that they have customers at all. Certainly they have not looked on the industry in this role. However, the current competitive funding regime is increasingly forcing them to confront the reality of the effect of student choice on university, faculty, and departmental fortunes.

The issue of suppliers and customers in education is taken up further in Section 4.5, below.

4.3.1 Where the students fit in

The position of the Federal Government, which expends over $5 billion on universities, is that "students are the most important thing in the university system". The need to attract students is indeed the most important constraint under which universities must operate - without students there would be no universities. However, a short time spent in a university is all that it takes to conclude that teaching students is not the reason that most academics choose to join universities. It is as well to acknowledge that there is a fundamental tension between the purposes of the funders and the purposes of those receiving the funding.

This tension becomes concentrated in discussions on the link, or lack thereof, between teaching and research. It seems widely acknowledged that there is little correlation between an individual's skill in teaching and in research. Some are good at both, many are good at one but less so at the other, and the system generally works to ensure that there are very few who are are good at neither. However, it is universally maintained within universities that it is not possible for a *department* to maintain a high overall standard in its courses if research is not also conducted within that department.

There is a more subtle point here. Universities tend to judge the standard of a course by its content, rather than by its presentation. At least for universities that have attracted the brighter students, the view has long been that if the students are 'any good' they will rise above poor teaching. This is often backed by personal anecdotes recounting how "I learnt more about [that] subject than any other because the lecturer was so bad." This doesn't pass muster as an argument in favour of poor teaching, but there is something in it. Furthermore, turning the argument around, there is no doubt that an out-of-date syllabus, no matter how excellently taught, will rapidly condemn a department to a second-rate status.

The quality of teaching is clearly important, but students only really find out about it after they are enrolled, guidebooks and 'alternative handbooks' notwithstanding. Its importance in attracting students can therefore be over-rated. Broadly, students know where the good students have gone, and have a fair idea of which graduates are getting the good jobs. These are more important factors in student choice.

4.3.2 Choosing a university

There is a strong sense that there is at least a two-tier system in operation in attracting students, although few seem willing to admit it. Thus some departments report great difficulty in attracting students to stay on for an Honours degree. The HECS charge and the loss of a year's paid employment

make a fourth year economically unattractive to some students. At the same time there are historically high numbers of the brightest students undertaking five-year combined degrees. The two groups are evidently driven by different imperatives. Universities will target the two groups with different marketing approaches.

It was ever so. A story going back over two thousand years recounts how a student asked Euclid what was the value of studying geometry. Euclid's response was to give the lesson, hand the student a coin, and expel him from the academy.

Whether students are driven primarily by an expectation of enhanced employment prospects, or by the thirst for knowledge, if the industry wants to employ them it has to make itself attractive to them. In this regard the industry has sent universities, and through them, the students, a rather mixed message about what courses and universities they favour. As recounted in another section, when times are tough graduating from a specialised course is no guarantee of a job, but when times are good the industry will take just about anyone. Some companies clearly favour certain universities over others, even if the course content is not specifically tailored to their expressed needs.

Added to this is the particularly Australian expectation that university education in just about any field should be available at a local university, and preferably one which is located as conveniently as the local high school. Illustrating this, a lot is heard about the reputed difficulty of attracting Perth students to enter the first-year of the Curtin (WASM) university courses in Kalgoorlie. Some have also suggested that parents in Kalgoorlie may be equally reluctant to see their 18-year-old offspring move to Perth to start university. On the other hand, mining and minerals courses in cities such as Brisbane have not drawn significantly greater numbers of students. The question remains: is it the location or discipline that has relatively limited appeal?

Those within the industry occasionally express puzzlement as to why a career within it appears to have limited, or perhaps specialised, appeal. Quite bluntly, the industry has a bad image amongst the school population. Despite some notable efforts, which must include Alcoa's outstanding achievements in conducting its operations virtually at Perth's doorstep, the industry has not overcome its poor reputation on environmental damage and workplace safety.

This aside, the expectation of a local tertiary education is also sustained by the system by which universities operate under state laws, but Federal Government funding. Claims by States for equitable funding for the benefit of their citizens help to ensure that education facilities are spread around the country. In fact there are few fields in which studies can only be undertaken at a handful of institutions; the veterinary area is one that comes to mind.

This expectation is endemic. It is reinforced by the inadequacy (putting it politely) of provisions for financial assistance to students whose choice of course (and university) would require them to live away from home. The United Kingdom provides a contrasting example. One of the calls made in the Chamber of Minerals and Energy's discussion paper was for rationalising the number of geology departments. This is just what has happened in the United Kingdom over recent years. However, this took place in a setting where it is the norm for students to leave home to attend university, and where assistance is widely available. It is harder to see it happening here.

The difficulty of achieving rationalisation is aided and abetted by the funding regime that rewards universities in proportion to student numbers. Since the minerals and energy industry is seen as being attractive to students, no university would willingly give up the possibility of claiming to prepare students for jobs in it. At least, not without getting something in return.

In short, education is business, and student numbers are the keys to survival. Educators look upon the minerals and energy industry in the same way that the industry regards mineral deposits.

The worst outcome would be if local universities followed the path alleged of certain others, where resources are diverted from teaching to student amenities in an effort to boost numbers.

4.3.3 Marketing the university courses

The various universities are setting out to establish niche markets. Their aims are to attract students, and the approach is to promote courses of study on the basis that they will enhance the graduate's career prospects. This means that they are presented to students in terms of their supposed or demonstrated appeal to employers.

Curtin, particularly in the Western Australian School of Mines, runs long-established mining and metallurgy courses focussed squarely on producing graduates with skills that will make them productive immediately upon taking up employment. This allows it to emphasise that the hands-on aspect of the education they provide enhances the employment prospects of the new graduate in the industry. They advertise the advantage to the student's employability that flows from close involvement with the industry, and especially vacation work experience obtained 'in the field'. The formation of a new Faculty of Minerals and Petroleum has as one its aims the facilitation of the marketing of Curtin's courses in the minerals and energy area.

The University of Western Australia is taking a different marketing approach. At present its undergraduate courses, other than geology, do not have a strong focus

on employability in the minerals and energy industry. However, it aims to change this with its proposed courses in resource engineering.

UWA will advertise them as equipping the graduate for a wide range of career options in the resource sector. The vision is that graduates will be attractive to the minerals and energy industry, but that they will not be committed to it from the time they enrol. Furthermore, there are other sides to the 'resource industries' beyond minerals and petroleum, and graduates will also be equipped for a career within these.

Maintaining UWA's record of attracting students with the higher level of Tertiary Entrance scores from high school is a critical factor in its marketing. This becomes a marketing feature on the grounds that the student benefits through association with the 'brightest' people (in terms of the entrance criterion) in the age cohort. The claim is that leading companies will seek out the UWA graduates for their potential rather than their immediate readiness for productive work.

Murdoch is taking yet another tack in promoting its new engineering courses. These can be taken in conjunction with TAFE, and the resulting range of options is presented as an attraction to students. Students can graduate after two years with a trade-based advanced diploma. Another year's study can gain a BTech. Eighteen months more study leads to a BE. This combination of practical trade skills together with the study of principles at university level is also presented as being highly attractive to industry.

Thus, the universities make judgements about what the industry wants. However, their marketing imperative is to convince potential students, not the industry, that their judgement is right. Whether or not they are right only shows up some three or four years after the student has made the commitment to the course.

4.4 CURRENT MOVES IN THE WESTERN AUSTRALIAN UNIVERSITIES

Analysis of the current realities of university funding explains why the industry often expresses frustration in its efforts to influence undergraduate teaching. Certainly, there are particular departments that are highly dependent on industry, and correspondingly responsive to it. However, overall, the industry sees that the training of its future graduate employees is precariously in the hands of an unsustainable proliferation of small departments. Indeed, history confirms the points made by industry concerning the difficulty of maintaining a presence for specialised departments when the resources are spread so thinly. Small departments are indeed likely to be swallowed up by larger ones.

So why don't the educators do something about it, by rationalising the number of departments that teach in specialised fields?

This is easier said than done. For one thing, other departments within a university may not be too unhappy with the prospect of smaller departments closing, and their quotas of student places being reallocated to them. But, by the same token, other departments cannot be expected to be as pleased with the prospect of any internal movement of students to a stronger rationalised department. In particular, getting a 'fair share' of service teaching to the large generic first and second year classes makes a vital contribution to most departmental budgets. Competition in the university system is not just between universities; it goes 'all the way down'.

Thus, while it may make very good sense for the University of ABC to relinquish its courses in a particular subject area to the University of XYZ, this won't happen through department-to-department negotiations. It has to be done at the highest level, and it has to involve a trade-off. We are now witnessing preparations being made in the local universities in readiness for such negotiations that might yet happen.

This section describes some of these recent developments.

4.4.1 The Murdoch School of Engineering

The current process of establishing a School of Engineering at the Rockingham Campus of Murdoch University makes an instructive case study. Again taking a broad brush to history, the situation appears to have been as follows:

- Murdoch University is too small for comfort within the current national higher education system; it saw that it has to increase student numbers.

- The communities in Perth 'south of the river' felt that they have not been adequately served with local university places. This is consistent with the general community expectation, referred to in Section 4.3.2, that students should be able to live at home while attending university. A couple of years ago they succeeded in convincing the Federal Government to provide the necessary funding.

- In a process involving the Western Australian State Office of Higher Education, competition between two local Councils, and competitive bids from two universities, Murdoch won the right to the new student places.

- The demographics of the selected area, Rockingham, were consistent with an engineering focus for the new courses, which also suited Murdoch's aspirations.

- **The particular branch of engineering (instrumentation and control) to be taught was then negotiated, incorporating advice from an industry group that, while not part of the minerals and energy industry is one of its providers of expertise.**

The close integration with TAFE is a particularly interesting feature of this development and is referred to again in Section 4.6.

Murdoch plans to expand the range of engineering courses it offers, and to strengthen the link between engineering and the well-established Mineral Science course, which is a major supplier of graduates to the industry.

4.4.2 The Watts committee

In part stimulated by the Discussion Paper published by the Tertiary Education Taskforce of the Chamber of Minerals and Energy of Western Australia in July 1996, the Director General of the Department of Minerals and Energy engaged Professor Don Watts to form "The Western Australian Mineral Research Centre Steering Committee". Prompted by the suggestions in the Discussion Paper relating to better use of existing facilities, the committee held discussions with a number of organisations. This included UWA, Curtin, and Murdoch Universities, CSIRO, State Government Departments, and major minerals companies.

The purpose was "to establish a Constitution for a Western Australian Mineral Research Centre/Institute which has the support of all the nominated participants, including the Western Australian Government ...". The steering committee's initial discussion paper reported a general consensus that the focus should be on minerals, rather than both minerals and energy.

Continuing discussion led to a second paper: "Emerging Views". These views by no means represented a consensus on all points. Perhaps the most fundamental point of difference was extent to which the proposed Centre would attempt to have a national impact. The alternative was to concentrate on achieving collaboration within Western Australia before seeking to be involved itself in national reforms. One area where there seems to have been general agreement was that "rapid change could not be considered a zero-cost exercise". State funding was considered vital.

With this the committee concluded its deliberations, and shortly afterwards Mr Colin Barnett, Minister for Resource Development, and for Education, announced that $1 million would be made available to pursue the formation of a centre for education and research in minerals and energy. This was first referred to as a National Centre, but is now the "Western Node" of a national system of centres. A committee has been formed to take this proposal forward.

It is notable that subsequent to these discussions all the university and CSIRO participants have consolidated and extended their positions in minerals education and research.

4.4.3 Restructuring at Curtin and UWA

In view of the above, there should be little surprise that Curtin University of Technology is moving to reconstitute its teaching under a new Faculty of Minerals and Petroleum. This will coordinate programs and, in particular, integrate programs between the Bentley campus and WASM. At the same time the University of Western Australia is establishing its Resource Engineering program. The undergraduate courses will allow a focus on mining, or mineral processing, or petroleum, with about 60% of the final-year content being in the selected specialist area. Although each of these courses will have a distinctive orientation, they will all build upon a strong theme of project management, and a concentration on principles rather than specific workplace skills.

Neither university is proposing major changes in staff or even of the subjects it teaches. Rather, the existing physical and intellectual infrastructure will be repackaged in ways that emphasise relevance to the Minerals and Energy industry. While there is clearly much concern about the level of competition within and between universities there has in fact been some flourishing of collaboration and sharing facilities. Both Curtin and UWA have significant Centres that cross departmental boundaries, and both have multiple involvements in the CRC program, as has Murdoch.

The status of the Western Australian School of Mines at Curtin's Kalgoorlie Campus is a critical aspect of the current positioning. Some recall that it used to be run by the Department of Mines, and consider that it should again be used as a State resource available to all universities for specialist teaching. Even within Curtin University its status is controversial. Some feel it is 'the jewel in the crown', while others consider that the disadvantages of its location in Kalgoorlie outweigh its benefits. Certainly Curtin has had a difficulty in attracting school-leavers to move from Perth to Kalgoorlie. However, it proposes to overcome this by offering the first two years of the WASM courses at the main Bentley campus.

In view of the wide level of concern about the duplication of resources in the education sector, there may be some comfort in UWA's intention contract specialised services and facilities from Curtin (WASM) for teaching its mining specialisation within its resource engineering program. Access to WASM facilities therefore appears to be a strong bargaining point in any negotiations that might take place on course rationalisation between the various universities.

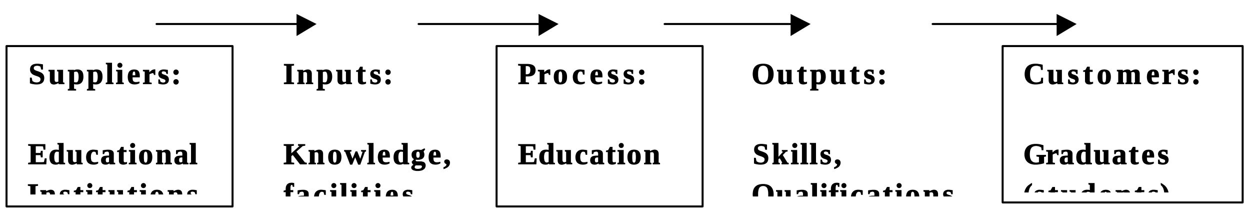
Overarching all discussions of the Western Australian School of Mines are political realities. Although WASM addresses State and National needs, it has a central role through the merger with TAFE to form Curtin University Kalgoorlie, in going some way towards the long-sought meeting of the educational expectations of the Goldfields region. The other major consideration is that only a few years ago the Federal Government provided some $12 million for capital improvements on the site, while Curtin has spent $3.5 million of its general funds on refurbishing the Mining building.

The industry should also hope that in this restructuring the universities succeed in finding a way of distributing funding within them that addresses the problems of specialist departments that are described in Section 4.5.3.

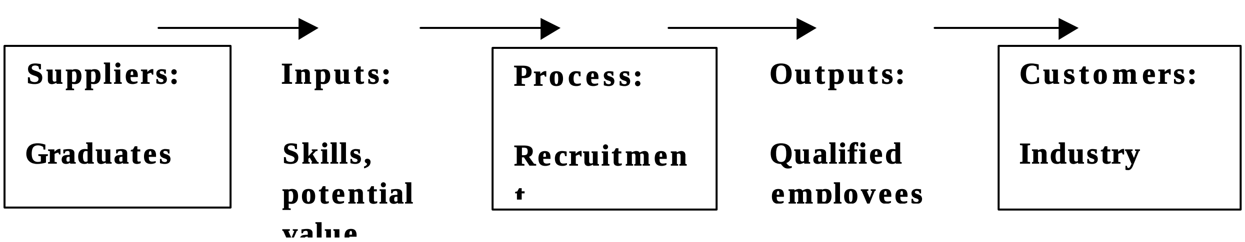
4.5 THE DYNAMICS OF INDUSTRY RECRUITMENT

In this section a systems dynamics model is constructed to help explain why the supply of graduates is chronically out of step with industry demand, and to suggest ways towards resolution of the problem. The situation in the training of geophysicists then used as a real-life example. This case also throws up another issue: the pressures that are falling on generalist departments, as well as on the specialist ones. Finally, the point is made that structural manipulations inside universities can't avoid the fact that specialist education is expensive.

Continuing the discussion started in Section 4.3, many of the characteristics if the education system can be understood in terms of the weak coupling between education for the industry and recruitment into it. This can be grasped by considering two production streams using the terminology of Suppliers, Inputs, Process, Outputs, and Customers (SIPOC).
One stream sees the students as the customers of an education process:



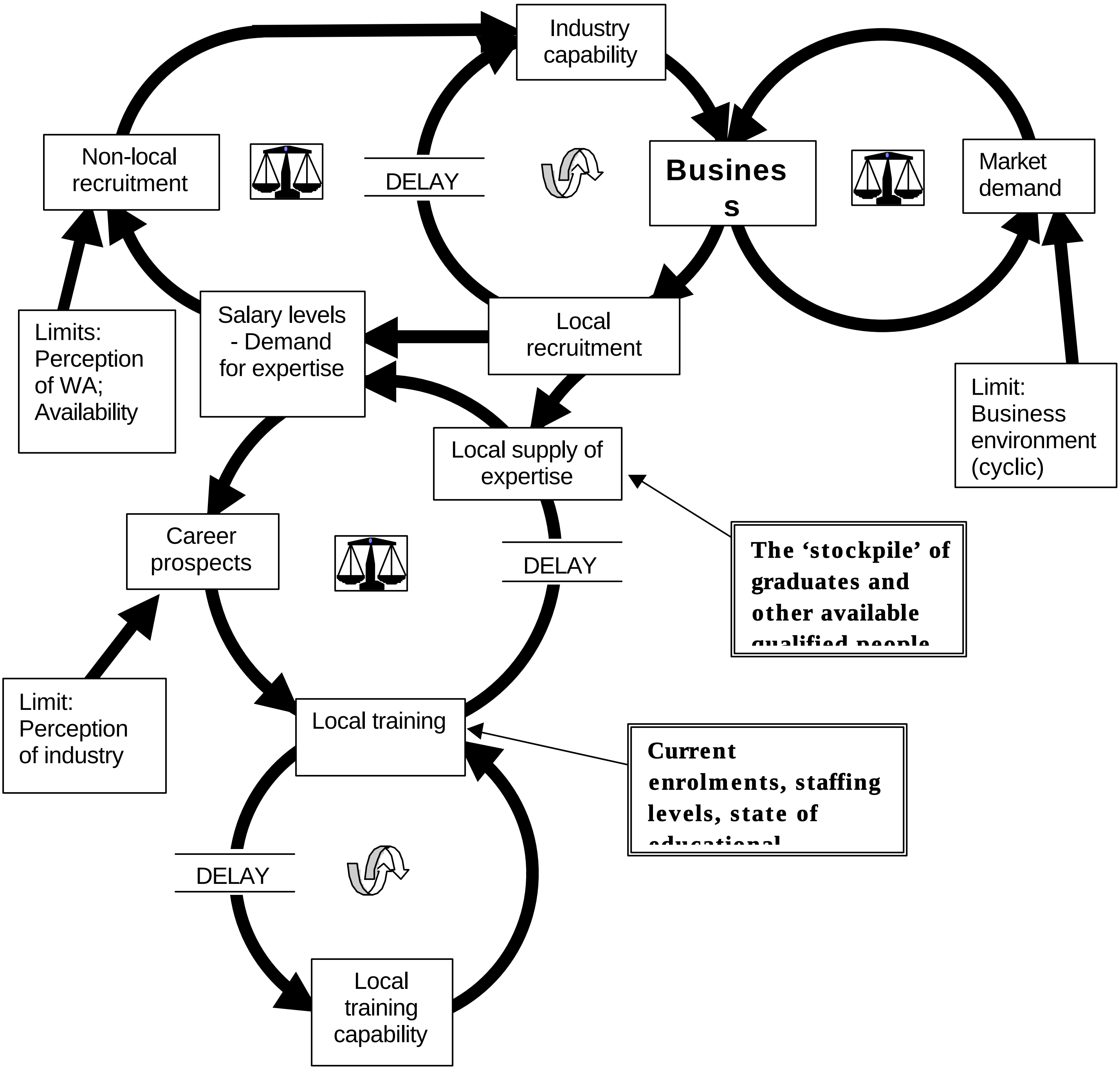
The second puts the industry as the customer of a recruitment process:



The main link between these two separate processes is the 'stockpile' of graduates who are available for recruitment. This leads to unstable dynamics because the supply of new graduates to the stockpile is largely set by the input of students to the education process three or four years beforehand. The following sections deal with this in more detail.

4.5.1 A system dynamics model for recruitment

The fundamental driver for recruitment by industry is its current condition of *business success*. **This self-reinforcing loop - other things being equal, more skilled people in a business leads to more success, and hence more recruitment. 'Other things' do not, however, stay equal indefinitely. Growth is balanced by demand for the industry's products, with an ultimate limit to growth set by the global factors that make the industry so cyclic. This can be neatly illustrated with a simplified system dynamics diagram, as described in Peter Senge's book** *"The Fifth Discipline"*. **Such a diagram for industry recruitment is given below.**



The system dynamics diagram for recruitment suggests ways of tackling the unstable combination of feedbacks loops with delays

The key features in these diagrams are that an arrow indicates that the state or condition written in the box at the tail of the arrow has an *influence* **(positive or negative) on the condition described in the box at the head. In many cases the effect of this influence is, however, delayed. The combination of self-reinforcing loops, balancing limits, and delayed effects give rise to complex behaviour over time. The results in this case are great fluctuations in the number of students entering the education process, and in the size of the stockpile of graduates available for recruitment.**

- ♦ **In this simplified model, an industry need for expertise leads to recruitment, which in the first instance will be local.**

- ♦ **After some delay as the new recruits come up to speed, this brings greater business capability. The loop is self-reinforcing and limited in both of the possible ways it can operate, as indicated by the double curved arrow symbol.**

- ♦ **This influences business success and the consequent need for more recruitment. At some stage, however, the market will turn down and demand for the products of the business will decrease. The scales symbol indicuates that this is a balancing loop.**

- ♦ **Decreased recruitment leads to a cycle of decreased capacity and decreased demand for recruitment until the market turns around again, hopefully before the company has gone out of business.**

The rest of the diagram shows the response to this business system. For completeness a balancing loop of non-local recruitment of experienced staff is shown. However, the focus is on what happens with local training.

- ♦ **Local recruitment (or lack thereof) immediately influences the local supply of available expertise - recruitment draws the pool down.**

- ♦ **The state of local recruitment, together with the local supply, influences the going rate for employing recruits - a measure of demand.**

- ♦ **This in turn influences two other conditions. If there is a local shortage there is a move towards recruitment from other places, and the limit to this (subject to availability) is the perceived desirability of moving to Western Australia.**

In the local scene the ultimate limit on recruitment is the perceived attraction of a career in the industry. If this is sufficiently attractive people will enter the training system, and after some delay, will enter the pool of people available for local recruitment.

The notable problem is the length of the delay in the training process. This may be as short as one year for a conversion course, is typically four years for a

graduate, and it is at least seven years before a school leaver could graduate with a PhD. Unfortunately, the business need for extra staff coincides with business cycles which seem run to a six or seven year cycle. This means that at a new enrolment at the peak of the boom leads to graduation in about four years, right at the depth of the bust. Moreover, as mentioned in Section 4.3.1, students enrolling in courses are well aware of the employment experiences of the previous year's graduates. The boom and bust cycle for graduate employment is thus accentuated.
Conversely, those with the determination or foresight to enrol during the industry downturn have historically enjoyed a great demand for their services upon graduation.

Moreover, there is another loop, also self-reinforcing, but highly damped by the delays in the system. The state of demand, after some delay, influences local training capability and capacity. Continued demand may lead to the building of additional facilities; continued low demand may eventually result in closure. In turn, this influences the amount of local training - the presence of good facilities tends to increase the number of people undertaking training, and vice versa. It can spiral in either direction.

The significant feature is that this is most directly influenced by the state of local training - measured by 'bums on seats'. This is insulated from demand by the delays in the training system itself. Eventually the state of business success in the industry exerts its influence but is highly distorted by these significant delays. It takes anything from five to ten years for a new department to be established and develop a reputation and presence that will attract students. Facilities could be closed overnight; however, the investment that they represent makes this a traumatic decision, which is never undertaken lightly. In practice, departments tend to die the slow 'death of a thousand cuts'.

The extent of the *personal* investment in developing capability in specialised education can hardly be overstated. It is rare for an academic to develop a significant personal standing before the age of 35. This means that at least fifteen years of such a person's life have been devoted to a specialised field before there is any chance of enjoying any of the fruits of having an independent reputation. The academic will have worked through two complete industry business cycles. Even a newly appointed but previously established academic will take perhaps at least three years to make a mark in the different setting.

4.5.2 Dealing with the dynamics

There are two basic ways of dealing with systems having delays in the influence loops. The first way is to develop patience and be prepared to sit things out. The academics have little real choice but to adopt this approach.

The second way of dealing with delay is to introduce greater flexibility into the system. This is what the industry does. If it can't recruit locally it recruits elsewhere, even if the cost is higher. If this is too expensive it makes do by recruiting non-specialists and bearing the internal costs of on-the-job training and development.

Another way of achieving flexibility could well be explored further. This is to delay the point at which students have to make a decision to specialise. There are examples of this. The University of NSW offers a degree in Petroleum Engineering in which students who have completed the first two years of suitable (but not specialised) engineering course at other universities may enter the Petroleum stream in third year (Petroleum Engineering is also available locally at Curtin). It is sometimes suggested that entry to the Western Australian School of Mines at Kalgoorlie could be through a mechanism similar to that used for Petroleum Engineering at UNSW. A number of students already transfer to WASM from UWA, or from other Curtin Engineering courses given at the Bentley campus in order to obtain a degree in mining engineering. However, this and the UNSW experience confirm that only a small minority of students is inclined to change universities during the course of an undergraduate degree.

Another related aspect of the option of delaying the decision to specialise is the growing perception that undergraduate engineering education may shift to a more generalist degree. Technical specialisation would then be achieved at the postgraduate level. This is already the case in some prestigious US engineering schools, and is driven at least in part by the need to cram more into the engineering undergraduate degree, e.g. safety, environment, management, etc. This is more attractive from the point of view of handling the shifting dynamics industry need than the alternative of increasing the length of undergraduate courses to five years spent specifically in the one discipline area

'Articulation' from TAFE to university also allows some compression in the time spent in the specialist stream. Some post-graduate (Masters) courses offer another route for more rapid response to perceived opportunities in the industry. The HECS charge is, however, regarded as something of a disincentive to part time post-graduation study. Students who are already earning above the threshold amount become liable to make repayment installments on the HECS charge at once. On the other hand, it seems that while students prefer to complete an undergraduate course at the one university, they are much more willing to undertake additional courses after graduation at other institutions.

The other principle that this diagram invokes is that the way to tackle limits to growth is by working on the limits, and not by trying to force the elements that drive the growth to operate even harder. Two limits, the supply of expertise elsewhere, and the global business environment, seem to be beyond the reach of any local influence.

One limit can only be addressed by the industry. This is the limit on entry to training set by perceptions of the attractions of a career in the industry. Where the Government has a role is in improving the perception of Western Australia (or Australia, if 'elsewhere means' overseas) as a destination. Reducing this limit could influence the supply of people to improve business capability in the shorter term. By ensuring that it is also a good place to study, the supply of local entrants to courses could also be enhanced.

4.5.3 An illustrative example - geophysics

An article in the May 1997 issue of the Bulletin of the Australasian Institute of Mining and Metallurgy draws attention to the troubled state of training in the field of geophysics. This is certainly a highly specialised field; it further subdivides into petroleum (seismic) geophysics and minerals (magnetic, etc.) geophysics. It is even necessary to ascertain what sub-branch people are talking about when they express views on the subject of training in geophysics.

Locally, the Department of Exploration Geophysics at Curtin (seismic) is said to have the largest graduating class of any comparable department in the World. Its Head sees a great opportunity for becoming the world centre for training in this subject. Yet it is reported to be at the very edge of viability.

Its graduates are certainly in demand. So much so that the industry is demonstrating its flexibility by seeking to recruit students before graduation. Not just signing them up in advance of graduation, but encouraging them to postpone their studies and start work during the third year of the four-year course.

Several other employers have responded to the high starting salaries generated by such demand by recruiting graduates in physics. Graduates with a more general physics degree do not have the specialised knowledge but are available more cheaply. The companies that do this generally have considerable in-house expertise available for training the new recruits. This hardly encourages educational institutions to invest in very specialised training designed around the specific needs of a sector of the industry.

4.5.4 The pressure on the generalist departments

However, one wonders at the long-term viability of employing physics graduates. This discipline is under considerable pressure at the moment. The University of Queensland has recently made severe cuts to its physics department so that while maintaining its service-teaching, it now concentrates its specialist activities on a particular area within the discipline. At Murdoch University physics is currently under review.

This exemplifies another move within universities that may not be apparent to people in the industry. The so-called generalist (i.e. non-vocational) departments are also under some threat internally. It used to be almost assured that, say, the mathematics department would teach mathematics to engineers. Now the tendency is for the vocational departments to say "we can teach our students all the maths they need (and collect the student units)". This will no doubt be backed up by claims that the service department has proved unwilling to (or incapable) in delivering the customer department what it wants. One can foresee the continued weakening of the generalist departments, together with an increasingly insular tendency in the specialist vocational ones. Such a trend doesn't even pay lip service to the notion that a university education should be a broadening experience.

The way that this is occurring mirrors the mechanism that the industry uses when it recruits generalist graduates in preference to specialists. Both situations amount to saying, in effect, that "we can train these people just as well, and we can make (or save) some money if we do".

There is a dynamic at work here that the industry might well find disturbing.

4.5.5 Structural issues

In the case of Exploration Geophysics at Curtin, part of the problem is seen as having to do with the internal structure of the university. Exploration Geophysics is a department separate from Geology, but the latter gets the bigger share of equivalent student numbers through service teaching in the early years of other courses. This is seen as stifling the viability of the specialist department. By the argument outlined above, there will inevitably be a pressure to seek to get some of teaching "back", and even to expand into providing service to other specialist departments in competition with Geology.

However, lest it be thought that size of department is the sole source of the difficulty, another example will show that being a specialised part of a larger department brings its own problems. The Centre for Strategic Mineral Deposits in the University of Western Australia is part of the Department of Geology. Far from being a 'bed of roses' this exposes a successful specialised sub-unit to all the pressures on a generalist department from the threatening forces described above. Funding has to be negotiated with all the other interests within the department. The response has been to develop direct financial links with industry by, in effect, selling membership to an industry supporter's club, which confers the right to access the Centre's expertise.

Specialised education is not free, and manipulating the mechanisms by which the costs are allocated in order to make it appear otherwise does not help to maintain its viability.

4.6 TAFE AND VOCATIONAL EDUCATION AND TRAINING

It would be fair to say that industry has experienced a degree of frustration in dealing with the VET (Vocational Education and Training) and the Technical and Further Education (TAFE) sector. Others have expressed this much more strongly. It is clear that increased focus on workplace skill over recent years has stimulated enormous demand for vocational education and training, and has heightened expectations about what is provided, and how it is provided.

The basis of the problems seems to arise from the extended period of flux (or even turmoil) that has immersed the technical training area. This is tied to the ongoing process of reform in the TAFE and training field. It has been in an almost constant state of change for some years as successive governments at State and Federal level have repeatedly re-defined their objectives for it. However, the developments described in this section give some considerable promise that the situation will soon improve.

Training and education at the technologist, trades, and operator levels covers a wide range of activities and training providers. The arrangements currently in place are complex and have not yet been fully stabilised, and this section only skates over the surface. There may indeed be some errors of detail in this overview, but it will give a feel for what is going on.

The acronym VET describes the broad field of training; TAFE refers to the continuing section of it that has developed from the former State-run Colleges of TAFE. Although training is under State Control, substantial funding flows from the Federal Government through the Australian National Training Authority (ANTA). In Western Australia the Education Ministry covers school education, and extends to university education only through the Office of Higher Education. The Department of Training covers the Vocational Education and Training (VET) sector.

The distinction that what goes on at school and in universities is ‘education’, and what happens at the level in between is ‘training’, is notionally neat, but is neither altogether obvious nor exact. For example, at some schools students can now start on a VET education during years eleven and twelve. Within TAFE there is a continuing duality of roles and courses involving the training and the further education aspects of its charter. TAFE continues to serve the community with courses with aimed at “general interest” rather than specifically at increasing the earning power of those undertaking the study.

The other major change is the recent opening of the training system to competition. In January 1997 the fifteen TAFE Colleges in Western Australia

were formally removed from the Department of Training's organisation. Fourteen became statutory authorities while the College at Kalgoorlie was amalgamated with Curtin University's Western Australian School of Mines to form Curtin University Kalgoorlie. This move has seen the Colleges becoming individual players within a competitive training market that embraces over 600 registered providers.

4.6.1 Competency-based training

There is widespread confusion concerning the terms 'Award Courses' and 'competency-based training modules'; they are frequently thought of as different TAFE offerings. In fact, the defining feature of the system is that *all* **TAFE education is now based on the building blocks of nationally accredited competency-based modules.**

There is some distinction between the two major types of TAFE offerings, although this is not absolute. These two types are Award Courses and industry-specific or customised training. Both of these make use of the modules, which are subject curriculum descriptions, in which the training outcomes are specified in terms of the competencies that the students must demonstrate. The former TAFE subjects have been restructured to this modular form, and new curriculum offerings must gain accreditation. The accredited curricula specify the content and the competencies, but do not specify how the subject is to be taught.

The stated aims of the recent major program of reforms to Australian vocational education and training undertaken by governments and industry have been expressed as:

- **training which integrates industry, enterprise, and individual needs and supports life-long learning**
- **competency-based training, achieving national industry and enterprise standards**
- **more flexible pathways and delivery**
- **increased access and improved outcomes for groups of people who have missed out on training opportunities in the past**
- **complementary roles for on-the-job and off-the-job training**
- **nationally recognised qualifications which are portable across industries and States and Territories**

- a broader range of providers who both cooperate and compete to meet national and international training demands

The idea behind these reform measures is the belief that they can do more to raise the levels of vocational education and training skills and qualifications in the workforce than can direct government funding.

4.6.2 Award courses and subject modules

Training to achieve industry-specified competencies is usually provided in courses comprising related modules. These may, but do not necessarily, lead to a range of awards, the levels of which are determined by the complexity of the competencies achieved. These awards cover the first six levels of the Australian Qualifications Framework, from the very basic skills of a certificate I or certificate II which are now also to be available through high schools, to the higher level Diplomas and Advanced Diplomas. Study periods to obtain these qualifications range from six months to two years full time.

Generally, higher level courses give TAFE graduates advanced standing at all universities (articulation) and in particular instances TAFE Colleges have negotiated additional credit for particular articulation pathways.

Essentially, Award Courses are substantially set programs of study available in TAFE Colleges to students for a nominal fee. Industry groupings will specify what combination of core and specialist modules they require, at various level of complexity, to qualify a successful student for, say, a Mechanical Engineering Certificate. Thus a student might undertake a full-time TAFE course after leaving school and before seeking employment; part-time study during employment is also common.

However, competency-based training allows a degree of flexibility aimed more specifically at employers who wish to arrange for their people to learn particular skills. It takes two forms:

- flexibility in the modules that can be incorporated into an Award course - these modules can be accumulated into a training package that is tailored to an individual's or company’s needs

- availability of modules for their stand-alone content, outside the framework of an Award course program

Flexibility is constrained in practice by availability. It is much easier to achieve flexibility with lower level subjects in which there are large classes than it is where class sizes may be uneconomically small; this is taken up further in Section 4.6.4. Reflecting these constraints, subject modules are available to employers on a range of financial terms. If enough students can be enrolled a

TAFE College may provide the module at the nominal student fees that apply to Award Course. If there is only a small demand the price may extend up to full commercial rates.

The modules may be given over a semester or in more compact blocks. The former is more common with Award Courses, and the latter is more common for industry-specific training or customised courses or subjects; it depends on demand.

The TAFE sector, like the independent registered providers, also offers a wide range of short courses on a fee for service basis.

4.6.3 Competitive funding

TAFE Colleges are no longer automatically funded for the training they provide. The funding arrangements that have emerged over the past two years have resulted in the Department of Training, as the State Training Authority, acting as the purchaser of training on behalf of both the Federal and State Governments.

In very general terms, the Department of Training oversees a process of determining the State's training needs. It then contracts out about 80% of this training directly to TAFE Colleges, for an agreed price, and tenders out the remaining 20% to all training providers, including TAFE Colleges.

This funding arrangement will be further refined in 1998 when employers of trainees and apprentices, in conjunction with the student, will be given the option of directing the funding allocated to each student's training to the provider of their choice.

The options for presenting competency-based training modules are very flexible. They may be presented in a TAFE College environment, in a private provider's own training facilities, or they may be presented in-house at the workplace. Successful tenderers also sometimes sub-contract work. Thus, it has happened that a successful tenderer, who doesn't possess the necessary staff or physical resources to present a module, has sub-contracted the work to the very TAFE College that was unsuccessful in the bidding process. In this case the sub-contractor has, in effect, undertaken to administer the presentation more cheaply than the College had proposed to do, or has been prepared to subsidise costs from other sources.

Growth in the number of training places must now be achieved through efficiency gains within the existing funding. Where specific skill shortages can be identified the approach is to develop and fund a specific program to address that shortage, rather than to adjust the emphasis of the State's overall training program. A recent example of this is in the Metals Trades area, where specific funds have been allocated to address skill shortages.

4.6.4 Problems with specialised courses

The outcome of VET study is aimed at employment, rather than knowledge, and this puts more pressures on the system. The offerings must be matched to labour market demand; complaints will arise from students if they can't get jobs. However, demand for efficiency makes larger class sizes - at least above a minimum of between 12 and 16 - a prerequisite for modules that are funded through the contracts with the State Training Authority. The ideal for a TAFE College is a large class in high demand.

At the same time there are valid requirements for training in specialised engineering areas where it is proving difficult to maintain classes of the required size. This is just the same sort of problem that faces university departments teaching specialised courses for the minerals and energy industry.

This leads to a problem that is now being reported in some engineering industry sectors. While there has been an increase in trained operators there is now a shortage of supervisors. The lower level awards generally attract larger classes, particularly because core modules can accommodate students from several Award Courses. The difficulty is at the higher level modules. Industry insists that these are necessary to give potential supervisory staff the contextual knowledge to make process improvements and to direct the work of those who only have competency in limited areas. The difficulty is that class sizes are often below the 12-16 cut-off that TAFE Colleges require to justify presenting a module through their contracted funding arrangements. This may in some cases be resolved by running larger classes at operator level, provided safety considerations can be satisfied and, of course, if there is sufficient demand for the module.

This is exacerbated when the training requires access to expensive equipment. Private training providers prefer to concentrate on low capital cost courses, such as business studies; they are less inclined to invest in (say) NC machining centres for mechanical training. The TAFE colleges are then left to service the more expensive courses, but apparently the current funding models do not make allowance for this. An alternative in some areas of technology is to move more towards on-the-job training, but this is not attractive to employers where this involves a real risk to production. There is a real problem here.

It might be easier to get larger classes if TAFE Colleges rationalised their offerings so that all students in a particular specialised field could be concentrated into one class. However, the competition between the 14 autonomous TAFE Colleges does not appear to lend itself to such an outcome.

Again, there are obvious parallels with the competitively-funded university system.
Industry is now facing the reality that the benefits of flexibility in competency-based training have come at the price of the 'user-pays' principle. This principle does, however, allow some ways around the problem. It would apparently be open to an employer to pay full market price for a particular module to be taught for even a single employee. It would even be possible to accumulate credit for all the modules required for an award on this one-at-a-time basis. The student could then enrol for the relevant Award Course, claim credit for all the modules already completed, and receive the award without further study.

This would be a very expensive process. It is hardly as attractive as the virtually free education (except for nominal student fees) that would be available if the class sizes were large enough. Employers to whom it has been suggested have not been inclined to take it up. However, enquiries around this topic have revealed some 'grey areas' in funding arrangements, so there may well turn out to be some intermediate path. For example, there are some alternative funding channels available. The Commonwealth Department of Employment, Education, Training and Youth Affairs (DEETYA) provides funding for some Industry Traineeships run within the VET system.

These considerations may seem a bit far-fetched, but they really are very relevant to the minerals and energy industry, where the need for higher-level supervisory people is pressing, but the numbers required are small. This sort of concern has led to the complaint that while industry needs people of varying levels of skill and training, the educational system is moving to produce only university graduates and people competent in certain limited skills.

Others would disagree with this characterisation, and point out that the system of articulation allows progression from level I (trade) through to a university degree. As the example given above demonstrates, the critics maintain that the funding of the TAFE system does not in practice encourage this.

This reinforces a claim that a succession of Australian Governments has demonstrated a lack of comfort in maintaining true multi-level education systems: "they want to make it 'either-or' when we need both". There certainly seems to be something in this assertion. In a previous restructuring the higher levels of the former Technical College system had become Colleges of Advanced Education (CAEs) while the TAFE Colleges comprised the remaining lower levels. However, almost immediately pressure mounted within the CAEs to attain degree-granting university status. The dual university-CAE system lasted only a few years; the TAFE sector is already moving into degree programs. Time will tell if the present attempt at an integrated system has a future.

4.6.5 Student charges and student perceptions

The TAFE system has a nominal up-front student fee, rather than the HECS charges that apply within the university sector. The TAFE fees are collected by the individual Colleges and are additional to the public funding received by the Colleges. In contrast, the HECS charges are collected as government revenue and are designed to provide a return on the government funding of university places.

New and innovative ways of achieving desirable outcomes for students within the post secondary environment are currently undergoing trial. For example the developments between South Metropolitan College of TAFE the new Murdoch School of Engineering at Rockingham, described in Section 4.4.1, are seen as a very promising way forward. However, the university also has to get something out of such a deal. One benefit is access to up-to-date industrial equipment, with which some TAFEs are well endowed.

As an example of this, the Advanced Manufacturing Technologies Centre (AMTC - an autonomous College within the TAFE system) provides some 'high-tech' university subjects to Curtin and Edith Cowan Universities. On the other hand, the universities that enrol articulated TAFE students into later years of their courses have to balance missing out on cheaper-to-teach first-and second-year students (high value EFTSUs) against picking up senior students where the class sizes are often uneconomically low. Negotiations have to take place on a case-by-case basis.

The proponents also point out that through arrangements such as those being made with Murdoch University students can avoid two years' HECS charges in gaining a university degree. One wonders how long this will last.

Concurrently with these initiatives the TAFE system is working to remove the long-held perception that TAFE is cheaper, but a sort of 'second prize,' in comparison to university. It appears that students are now beginning to see TAFE as the more prospective route to employment than a generalist university degree.

4.6.6 Industry Training Councils

There is a formal role for industry in the operation of the State's TAFE system. There are fourteen Industry Training Councils (ITCs), mainly State- and partially Federal-funded, each having an employed executive and a voluntary governing Board drawn from industry. Specific industry input comes through industry panels covering particular areas. The ITCs most directly relevant to the minerals and energy industry are the Mining ITC, the Process Manufacturing ITC, which covers aspects of the hydrocarbon industry, and the Australian Drilling ITC.

In general, the ITCs have only an indirect impact on TAFE Colleges. Through surveys that they conduct, they provide advice on expected training needs through the State Training Board as input to the State's Industry Training Plan. In turn this is incorporated into the State's three- to five-year Training Strategy. These requirements end up as student places, for which the TAFE Colleges make competitive bids, consistent with their approved profiles.

ITCs may act as brokers in putting courses together for the industry, and have been active in drawing up National Modules. They have a role in course accrediation and registration, however, they are not necessarily big users of the TAFE Colleges. In the hydrocarbon part of Process Manufacturing, it was explained that in many cases either the industry has its own courses, or it relies on in-house training on its own specialised equipment and processes. Quality assurance for courses and providers of training is a critical issue under the requirement sof the safety case regime under which the petroleum industry operates.

It is said that each ITC is very different. The particular direction taken by an ITC, and its effectiveness, is said to depend very much on the activity and composition of the Board and its relationship with the staff, who, as noted, are paid by Government.

4.6.7 The newly autonomous TAFE Colleges

The Colleges have lately been developing their customised training agency arms in order to compete with private training firms. This has been a growth industry, spurred-on firstly by the now-abandoned training guarantee levy, but continuing as firms decide that, like so many other things, in-house training is now no longer their 'core business'. The field has, however, become crowded and very competitive. There are no 'easy pickings'.

With the new regime of competition, the Colleges are becoming much more entrepreneurial in chasing business. This is not seen as an unalloyed benefit. Competition has been substituted for a more centralised control without a clear means of enabling coordination. This seems to be causing some difficulties all round, as colleges complain about poaching by rival colleges. At the industry end it has been remarked that "We encouraged autonomy because we hoped it would make them more responsive. But we're the only ones with money, so now we have all 14 pestering us." Inside the sector itself the situation has been described as "a scattergun, uncoordinated scramble for students - bums on seats".

The new competitive training environment has seen the Advanced Manufacturing Technologies Centre (one of the autonomous TAFE Colleges) has established an oil and gas training facility at its Wembley campus, and the private Petroleum

Industry Training Centre plans to build soon on land adjacent to the site of the CSIRO Petroleum and Minerals Resources Research Centre. In this environment the ITCs do not appear to have been the complete answer to coordinating training needs. Thus, a new group, the Australian Hydrocarbon Industry Training Service (AHITS) is in the process of setting up with the stated aim of catering specifically for the needs of oil- and gas-producing operators. Rather like an ITC, it will define what the industry sector that it represents wants and will call for bids from private training providers. Like the ITCs, it is has its critics and the extent of its industry backing is not yet clear.

The Petroleum industry is seen as attractive to entrepreneurial training providers. It is an industry where constant training is seen as vital, particularly under the safety case regime of operation. At the same time, wages in the industry are high, and numbers of operators are relatively low, while cost pressures are increasing with little likelihood of relief through higher prices. This suggests to some that the industry will respond to the need to reduce non-operating costs by increasingly outsourcing its training. It is felt that there are real opportunities for trainers who can supply this globally oriented industry, which is caught between costs of high operator wages the need for high standards of operator competence

In contrast, the minerals industry, although larger, is seen as diffuse in its needs, and less able to give a clear direction to trainers. Wages are lower than in the oil and gas industry, and with the small mines, operators are expected to be useful as soon as they start. There is not the same track record in providing training. Altogether, the minerals industry is seen as a less rewarding area for trainers.

However, despite these challenges, the minerals area is a market for training. A concept paper published by the Peel Development Commission towards the end of 1996 flagged the possibility of developing what is essentially a private training venture aimed at the mineral processing industry. The initial target is the processing industry south of Perth, based on alumina and mineral sands. However, the concept is also being developed to target South-East Asia.

It is clear that the sector has not yet fully settled down; 'Canberra' continues to grapple with the national training agenda. As this situation stabilises it is expected that Colleges will begin to focus more on mineral and energy industry sectors, including aspects of mining, downstream processing, and laboratory services. One concern that they are already beginning to address is staffing. There appears to be uncertainty in how colleges should be staffed, and concern about current staff, particularly their high average age. The need for a highly competent and industry-relevant staff to provide the training services to the industry is clearly acknowledged and being addressed within the TAFE system.

4.7 PROSPECTS FOR GROWTH IN THE EDUCATION INDUSTRY

People recite the list of Schools and Departments, once famous in minerals and energy teaching in the UK, the USA and Canada, that have recently closed, or whose fortunes are at a low ebb. Of other countries Chile has been mentioned as possibly being interested in developing its minerals education system to a leading status within the next five to ten years. Language does not seem to be regarded as a major problem with Chile, but it is seen as barrier against access to other educational resources, such as those in China.

Australia is seen as being in an unmatched position to become the World's leading centre for training in mining and minerals - and also in some aspects of petroleum exploration. The catch is that there is held to be only a period of maybe five years to realise this opportunity.

Indeed, educators in both university and TAFE sectors in Western Australia are currently very excited about the prospects of tapping into the global Minerals and Petroleum industry demand for graduates. This enthusiasm comes across to many people, particularly in other States, as a bit naïve. These critics do have a point in doubting the ability of Western Australia to 'go it alone', at least to the extent as it has come across. This State could hardly claim to have anything like the involvement that, say, Queensland has with, e.g., coal, or underground copper mining. Nevertheless, no one doubts there is an opportunity, even if Western Australia is unlikely to be able to claim the entire prize for itself.

4.7.1 Marketing university courses outside Western Australia

The competitive marketing strategies adopted by local universities (Section 4.3.2) do not make it any easier for the State of Western Australia to present itself elsewhere as a centre of minerals and energy education. The form of marketing adopted by the universities sets a path by which the individual institutions will advertise themselves in their own right, just as they do locally. This is what universities are already doing with other subject areas.

This means that the State would have to present itself as a collection of educational institutions rather than a centre *per se*. The result would be that prospective students would have to be attracted by the prospect of a choice from a number of different competing institutions and courses in a rather specialised vocational area.

There are indeed great educational centres where competing institutions contend for student allegiance - Boston comes to mind. However, these institutions have strong individual reputations for excellence, and part of their attraction is the breadth of educational experiences that they can provide. They have not become famous by offering competing vocational courses in the same fields. Indeed, there are no obvious examples anywhere in the World where this approach has been the path to success.

Moreover, when the prospective students for a minerals and energy education in this State enquire a little deeper they will find some less attractive features. Transferability between courses is limited, so they are substantially locked into their choices. Furthermore, they may become subject to concerns about viability of their selected courses resulting from this fragmentation of resources.

Universities are setting very ambitious targets for the share of revenue they expect to obtain from full-fee-paying (mainly overseas) students. The sceptical observer may consider that successful promotion of such growth to date has depended more on value for money, combined with an attractive study environment in Western Australia, than it has on offering particular specialised courses or specific academic excellence. It may certainly be questioned whether this will continue to be sufficient as the present catchment areas develop their own tertiary education systems.

In any case, the State certainly has a major role in attracting overseas students simply through maintaining a safe environment, good cultural and sporting facilities, and available accommodation.

There is an alternative to attracting students to Perth; this is to set up in the target country. It is understood that the University of Aberdeen has now established a presence in Petroleum Engineering in Indonesia. It would be unwise to assume that the opportunities will last indefinitely.

4.8 CONTINUING PROFESSIONAL DEVELOPMENT (CPD) AND DISTANCE EDUCATION

The need for continuing education and training throughout a working life has become a current truism. This has become formalised in many Professional Institutions which are increasingly requiring continuing professional development (CPD) to maintain registration as a practising professional (Section 2.8.2).

Acceptance of CPD has been matched by the growth of ways to satisfy the need. Furthermore, it is unlike initial education which is free, or substantially subsidised (even with HECS), and therefore comes with strings attached to its funding. Continuing education is paid for directly by the students and provides opportunity for profits to its providers, and for universities, untied income,

There is a long history of distance education (formerly “correspondence education’) in Australia and some universities target this form of education quite specifically. University degrees are available in a great number of fields, although mounting a course requiring a large proportion of hands-on laboratory

work poses practical difficulties. The provision of local study centres, fast telecommunications links and visiting tutors continues to make distance education an increasingly viable option for people in remote centres. Moreover, a considerable number of people who are within reach of on-campus education elect to study by distance education because of the flexibility it allows in combining employment with study. In short, distance education is already a well-accepted mode of delivery.

This section makes no attempt to survey the field. It simply points out that just about every significant player is already involved. Universities, TAFE Colleges, Professional Institutions, Technical Societies, industry groups and others are all active as competitors or niche marketers. The Western Australian universities are already active in distance education in the minerals area. However, some universities based in other states have already developed reputations as providers of distance education and have made considerable inroads into the Western Australian market in other fields. The provision of distance education from other states into the minerals and energy field can be expected to grow.

to Offerings already range from short courses on industry-specific topics (e.g. as presented by the Australian Minerals Foundation) through to Master's degrees. They include undergraduate degrees for people holding certain TAFE qualifications - e.g. as is available through the Institution of Engineers, Australia's subsidiary Engineering Education Australia in conjunction with Deakin University and the University of Southern Queensland.

People undertaking CPD must usually fit it in with their normal employment. This means that part-time evening-study programs, short one- to five-day units, and 'distance education' courses predominate. The term distance education includes traditional correspondence courses and extends to later multi-media deliveries by broadcast, telephone and video link, and the Internet.

Once distance education is accepted the World becomes a single education market. There is a long tradition of using overseas-developed home study correspondence programs. United States engineering schools are active now in developing Internet-delivered subjects that will be accessible anywhere. There is little doubt that local universities will begin to tap into these for their own students, and no reason in principle why they cannot compete in providing subjects or modules of their own to the World.

The practical considerations to bear in mind are that developing distance education material is not cheap, and that there has to be a market for the product. Those who can afford to undertake this will be those who have a substantial base of local students for whom the material has to be assembled anyway.

There may have been easy pickings in this area at one time, but no longer. There is a lot of competition and the customers are increasingly concerned about value for money. This reflects the changing patterns of employment where companies are now less inclined to support the professional development of their staff. This is likely to be considered increasingly the responsibility of the individual.

APPENDIX A: TERMS OF REFERENCE

Identify from the Western Australian Mineral Industry's perspective the key issues related to

1. **the industry's technical needs**
2. **the need for, and value of external research**
3. **current education and training services**

APPENDIX B: TIAC STEERING COMMITTEE

Rex Baker (Chairman and TIAC member)

Dr Nigel Radford (TIAC member)

John Thompson (Chairman of TIAC)

Dr Colin Branch (representing the Department of Minerals and Energy)

Dr Jim Limerick (representing the Department of Resources Development)

Dr Sue Meek (representing the Department of Commerce and Trade)

Earl White (TIAC Executive Officer)

APPENDIX C: CONTACTS

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Operating Companies

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Bob Bourne	Normandy Group
Eugene Dombrose	WMC Resources
Simon Gatehouse	North Limited
Dr Bob Gunthorpe	Normandy Group - Exploration Division
Phil Hunt	WMC Resources
Keith Kenny	Acacia Resources
Malcolm Richmond	Hamersley Iron
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Western Australia's Minerals and Energy expertise - How can it be optimised? - Defining the issues: a background paper

Prof Don Watts **University of Notre Dame Australia**

CSIRO

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Dr Mike Hood	Centre for Mining Technology and Equipment (CMTE)
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Leo Verjans	Process Manufacturing ITC

Industry associations

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Dick Davies	AMIRA
Dudley Kingsnorth	Materials Institute of WA

Other service providers

Michael Mulroney	Rothschild Australia
Chris Wiggins	Rothschild Australia

APPENDIX D: BIBLIOGRAPHY

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APPENDIX E: GLOSSARY OF TERMS

AMIRA The Australian Mineral Industry Research Association. This is described briefly in Section 3.2.2.

Cost curve The idea behind the cost curve is that it indicates which producers are most vulnerable to a fall in prices or in demand. The cost curve for a product is a graph of production cost against total production. The first point on the graph, at zero production, is the production cost of the lowest cost producer. Successive points represent the cost for the next-lowest-cost producer, placed against the total production of all the cheaper producers. The result is a rising curve on which the cheaper producers are positioned towards the left, and 'lower' on the curve.

The most vulnerable producers are those who are 'higher on the cost curve'. Commonly, the cumulative production is divided into quarters ('quartiles'), and a producer whose costs place it in the 'top quartile' is considered at risk. The entry of new large low-cost producer has the effect of pushing all the established higher-cost producers 'up the cost curve'.

CSIRO The Commonwealth Scientific and Industrial Research Organisation - by far the largest research organisation in Australia; its many Divisions cover a very wide spectrum of industrial and agricultural research. The majority of its funding comes from the Federal Government.

Cut-off grade Many mineral deposits do not exhibit clear boundaries between the mineral and the ground that surrounds it. The concentration of valuable mineral ('the grade') often decreases more or less gradually around the boundary of the deposit. In such cases the decision as to where to draw the limit to the resource is an economic one; below some grade the mineral is too expensive to extract with available technology. The 'cut-off grade' marks the current economic boundary of the deposit. An analogous situation exists in the petroleum industry; at some point it becomes uneconomic to continue pumping from a well. An exhausted oil field may still contain a considerable fraction of the petroleum originally present.

Downstream The production stream for mineral processing starts with mining. As the mineral is converted into metal (or a petroleum product), and ultimately into finished goods, the processing is said to move 'downstream'. Conversely, 'upstream' refers to operations closer to the original point of extraction.

EFTSU Equivalent Full Time Student Unit. This is a standardised measure of student enrolment in the university system. A part-time student would count as a fraction of an EFTSU, while a postgraduate research student, who is present for the whole year, rather than just for the university undergraduate teaching period of the year, rates more than one EFTSU.

MERIWA The Minerals and Energ y Research Institute of Western Australia. This is described briefly in Section 3.2.2.

Minerals and energy industry
In the present context the term minerals and energy industry is a convenient shorthand for the industries that extract resources from the earth. Thus solar and wind energy (for example) are excluded, even though MERIWA (see above) has broadened its coverage to include solar energy research. The energy component refers to coal, oil and natural gas, which are burnt to produce energy. Minerals are either refined into metals (such as iron and nickel), refined into other chemicals (such as titanium dioxide), or used in their natural form, possibly after some physical upgrading (beneficiation), as industrial minerals such as talc. Classifications are conventional rather than exact; the uranium industry could arguably be placed in either the mineral or the energy category.

JKMRC (the 'JK') The Julius Kruttschnitt Mineral Research Centre - a notably successful externally-funded research centre within the University of Queensland, described in Section 3.4.

Life cycle The idea of a life cycle is to indicate some measure of intensity of use as a function of time. Examples are the consumption of steel per head of population, or the number of mobile phones in use, etc. There is a consistent pattern by which demand for a new product initially increases very slowly, then 'takes off' rapidly, before demand 'flattens out' as the product becomes a 'mature technology', and eventually falls away as new products are substituted for it. Some life cycles are very short, as with home entertainment systems, while some are very long, as with the use of steel or aluminium.

Petroleum Petroleum refers to liquid or gaseous hydrocarbons extracted from reservoir strata in the earth by drilling. The usage to denote a section of the industry is conventional rather than exact. For example, extraction of oil from tar sands is a mining operation, although its subsequent processing and marketing would class this as a petroleum operation. Similarly, large amounts of methane (a hydrocarbon gas) are associated with coal. This is recoverable in some circumstances, but its recovery is regarded as a mining operation rather than a petroleum one, even though the gas may be extracted through wells.

Technology A useful working definition of a technology is that a business can be said to possess a technology X when it can say “we know how to do X”. For example, “we know how to discover gold deposits”, “we know how to operate a mine”.

Toll smelting Some of the more flexible smelting processes are capable of handling a wide variety of input ores and concentrates. Rather than buying minerals to process, operators of such plants may provide a smelting service. The charge, or toll, takes into account the cost of processing the particular batch of material, which varies with the nature and amount of the impurities that have to be removed.

Upstream see ‘Downstream’, above.

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