Department of State and Regional Development

Audit and Review of Science, Technology and Innovation Infrastructure in Victoria

Report Volume 1

June 2000

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Executive summary

This is the report of the Audit and Review of Victoria's Science, Technology and Innovation Infrastructure. The Report is accompanied by:

- Volume 2: *Compendium of STI Organizations Based in Victoria* – which contains details about infrastructure assets, capacity and capability and collaborative arrangements
- An *STI Database* in electronic format – which contains more detailed information about STI assets, fields of research and capability
- Volume 3: *Statistical Appendixes*- which include research and development expenditure details in Victoria and other supporting information.

STI infrastructure has been defined in *resource* terms. Infrastructure resources available at any point in time include tangible and intangible assets that are tied permanently or semi permanently to an economic unit – for example:

- Machinery and equipment
- Knowledge of technology
- Skilled personnel
- Intellectual property
- Organization and management competencies
- Access to funding for commercial application.

The definition emphasises *capabilities* that can applied in an innovation framework. We were concerned that a narrower facilities based definition of infrastructure would not capture the issue of distinctiveness that is critical for innovation. A focus on facilities would address, in part, the science and technology aspects of the Audit and Review, but would not address the innovation aspect. *Innovation only occurs where there is **application** of scientific and technical knowledge*[1]. Thus, the existence of a broad range of facilities is a sufficient, but not a necessary condition for innovation.

The focus of the Audit and Review is on capabilities that are available on a *collective* basis. It does not cover capabilities that have been developed for use exclusively within government, corporations or research organizations (eg. for discovery research purposes only). It is for this reason that Audit and Review has placed a great deal of emphasis on the forms of interaction and the arrangements for cooperation and collaboration within the research community and among the research community, businesses and government.

Information for the Audit and Review was collected through the following processes and procedures:

- A "Request for Information" sent to organizations involved in science, technology and innovation – based on addresses contained in *The Australian Research and Development Directory* and the *Technology Directory of Australia,* supplemented by organizations identified within the Department of State and Regional Development

[1] Because the Audit and Review is focused on Science, Technology and Innovation infrastructure, it does not address innovation in business processes, marketing and management strategy that may not have a significant science and technology input.

- An analysis of research and development expenditure data supplied by the Australian Bureau of Statistics
- An electronically administered survey of R&D performing organizations to identify strengths in R&D capabilities
- Collection of information from the Internet sites of research performing organizations.

The information clearly demonstrates that Victoria has a very strong capability in the areas of:

- Plant and animal production
- Mining and minerals
- Manufacturing
- Information and communication
- Health services.

A very strong research and development base and a tradition of close collaboration between the research community and industry in agriculture, mining and manufacturing support this capability. Collaborative arrangements are emerging in the health services area, particularly in the area of biotechnology.

Each of these five areas exhibits a very strong inter-disciplinary and trans-disciplinary approach to innovation. For example:

- Plant and animal production has a strong capability not only in the agricultural sciences, but also in applied sciences and technologies and the biological sciences
- In mining, there is a high level of capability in minerals processing, facilitated by the employment of high-tech enabling technologies such as computational fluid dynamics (CFD)
- In manufacturing, there are strong capabilities in applied sciences and technologies, physical sciences and information, computer and communications technologies. This data points to the *knowledge intensive* aspect of Victorian manufacturing, for example in materials sciences such as polymers and laser cutting, and is a major source of competitive advantage
- The high level capacity for simulation and modelling from within the information and communication sector has wide application for commercial and industrial users
- In the Health area there is also a strong interdisciplinary focus with substantial capabilities in applied sciences and technologies, mathematical sciences, and the physical sciences.

Overseas evidence points to the importance, from an innovation perspective, of the inter- and trans-disciplinary aspects of scientific inquiry and research and development, as well as collaborative arrangements between industry and the research community, for sustained industry development. Thus, while the health industry and biotechnology are receiving a great deal of attention in terms of opportunity for industry development, not only in Victoria but elsewhere in Australia, this industry must be able to compete effectively with the established capability and major markets for products located in North America and Europe. For this reason, the innovative capacity and capability of Victoria's agriculture, mining and manufacturing industries should not be overlooked.

To the extent that an STI strategy should build on strengths and overcome weaknesses, we consider that the following initiatives should be explored:

- Build on the knowledge intensive capacity and capabilities of the manufacturing sector, particularly in aerospace and other sectors that involve capital and knowledge intensive production
- Continue to build on the strong base in animal and plant production with the knowledge and skill base that exists in the Agricultural Institutes, CSIRO, CRCs and Research Centres
- Recognise the R&D capability in minerals processing or confront the possibility of it relocating to other states
- Encourage greater linkages between industry and the medical research community with the objective of providing frameworks for commercialisation
- Provide support for entrepreneurs in taking ideas and proven technology through to the commercialisation stages
- There is also potential to make greater use of computational capabilities in modelling and simulation.

Victoria's STI capability is located in numerous organizations. The following broad categorisation, based on organizations included in the *Compendium of STI Organizations in Victoria* produced in this assignment, indicates the scale and scope:

Organization Category	Number of Units Located in Victoria
CSIRO Business Units	17
Other Commonwealth research performing agencies	2
Agriculture Victoria Research Institutes	16
Universities	8
Hospitals	7
Hospital Based, Government and Independent Medical Research Centres	31
Cooperative Research Centres	22
University Based Research Centres	122
Total	225

The above listing does not include industry and professional associations or companies with a major STI capability. Many of these companies have a linkage to CRCs and University Research centres

The large number of organizations involved in STI activity suggests *potential* for fragmentation of innovative effort. While organisational distinctiveness allows for focussed pursuit of mission and purpose, lack of information about what is being undertaken in the broader research and development environment works against the development of inter- and intra-disciplinary cooperation and collaboration that is essential for innovation. This point was made on many occasions during the Audit and Review.

In addition, resource allocation mechanisms and competition for funding may work against collaborative arrangements. This is particularly important when addressing the issue of investment capital-intensive facilities and equipment. Moreover, knowledge of existing installations may obviate a need for new investment where access can be arranged.

The Audit and Review has collected a very large amount of information about capacity and capability in STI research performing organizations in Victoria. It provides

information that is useful not only for public policy purposes, but also for the research community, industry, and foreign direct investment, where potential investors wish to obtain information about research capacity and capability.

The information is presented in several formats:

- In summary form in Part 3 of this Report
- In text in the Volume 2 of the Report - *Compendium of Science, Technology and Innovation (STI) Organizations in Victoria*
- In electronic form, as an interactive database in the *STI Database.*

We would like to see a process where the information products provided by this project are regularly updated and revised.

A number of recommendations about the STI resource base are set out on the following page.

Recommendations

The following recommendations have been made in the context of the discussion and analysis of data derived from the STI survey and from discussions and consultations undertaken during the Review.

Part 1: Background and Issues

1 Introduction

This is a Report from an assignment that undertook an Audit and Review of Victoria's Science, Technology and Innovation (STI) infrastructure. The assignment was commenced in December 1999 and completed in May 2000.

1.1 Review purpose and requirements

The assignment had the objectives of providing:

- Authoritative information to underpin the assessment and selection of infrastructure projects for funding through the Government's program ***Investing in Innovation***
- Information on resources available for use by industry and research organizations
- An information base for Australian and global businesses seeking a high technology location for investment
- Information about the development of mechanisms to maximise the efficient use of infrastructure.

The brief required that the key STI research infrastructure located in Victoria be identified – including key equipment installations and related purpose built buildings and new developments.

The brief also required that the Audit and Review cover research infrastructure in universities, CSIRO facilities, DSTO, State Government research institutes and facilities and other research organizations, both privately and publicly funded. It was also to identify industry research infrastructure, which is used/accessible to researchers from other firms or organizations.

Specific comments were sought in relation to:

- The relationship between access to key infrastructure and the ability of the organization or user organizations to attract/maintain key personnel, research programs and research funding
- Clustering of activity around key infrastructure installations - including (but not limited to) Clayton, Parkville, Fishermans Bend and around the Alfred Hospital
- Mechanisms to update information on Victorian STI research infrastructure in a cost effective manner.

It was agreed at the commencement of the project that a greater emphasis was to be placed on identifying STI capacity and capability, and the interactions that take place in the form of cooperation and collaboration between the people and organizations involved in the operation and development of the STI base.

The change in emphasis was driven by the need to establish a realistic understanding of the way in which science, technology and innovation contributes to economic development in Victoria.

1.2 Definition of STI infrastructure

The Project Brief did not define infrastructure. However, it is well understood that the availability of infrastructure is a major contributing factor to economic growth and development.

A conventional view is that infrastructure is an asset that is available for collective use. It exhibits the characteristics of a "merit good". A merit good is anything that is judged, by whatever reason, to be more deserving of resources than market signals would suggest. In most areas of merit good activity, governments provide services, or support the provision by others, on the grounds that there is considered to be a consensus of collective responsibility to act in order to achieve particular goals and objectives.

Decisions by government to mandate, sponsor, underwrite or otherwise support the provision of services on a collective basis reflects the outcome of a complex interplay of factors such as:

- Industry representation and advocacy
- Ideas, ideals and objectives relating to -
  - National/state/regional economic development and growth
  - International relations and competitiveness
  - The role of government in supporting industry
- Economic theory and analysis, including matters relating to externalities and the existence of "public goods".

Infrastructure assets can be classified in terms of:

- *Physical Capital* - equipment, machinery, laboratories, etc
- *Human Capital* - skilled personnel, including scientists, engineers, R&D managers
- *Natural Capital* - the natural environment in which development takes place
- *Social Capital* - the networks and relationships that engender trust and collaboration between people
- *Structural Capital* - the management and administrative arrangements that plan, allocate resources and report performance.

The terms of reference for the Audit and Review have been interpreted to cover all aspects of infrastructure.

We do not regard privately owned assets that are not available for collective use as constituting "infrastructure". Thus, facilities and equipment used in the processes of commercial production, and which could not be accessed by other businesses for purposes such as research and product development would be excluded.

The definition of infrastructure in terms of an asset has a number of limitations in an industry and economic development context. In particular:

- The existence of an asset says nothing about its capacity for *innovation* – that is, the way in which can be used to generate new knowledge, invention and commercial exploitation
- There is a tendency to place emphasis on acquisition rather than access – which may be on a national or international basis
- There is a focus on "money" as solution to infrastructure gaps and shortfalls

- The importance of cooperation, collaboration and networks in the innovation process can be under-stated
- An asset focus underplays the importance of organizations and relationships between organizations.

As a basis for developing policies and strategies, it is useful to look at STI infrastructure from a *resource* perspective. Such an approach builds on the asset perspective, but can provide more meaning in a policy context.

1.3 A Resource Perspective of STI Infrastructure

A resource is anything that can be thought of as a strength (or weakness). The resources available at a given point in time can include those tangible and intangible assets that are tied semi-permanently to an economic unit, for example:

- Organization and management competencies
- Machinery and equipment
- Knowledge of technology
- Employment of skilled personnel
- Intellectual property
- Capital, including funds for the finance of innovation.

However, it is not enough to have strategic assets in order to create competitive advantage. Many strategic assets may not be unique, or can be easily replicated. For strategic assets to deliver competitive advantage, there must be *distinctive capabilities and competencies* that are difficult to replicate – at least in the short term. They can also be intangible and difficult to measure.

In the context of STI "infrastructure" the major focus of interest is on *resources* available for collective use – in either the public or private sectors. Initiatives and strategies for the creation of assets for collective use can come from either the public or private sectors – or in combination. Moreover, given the complexity of the relationships between science, technology and innovation, it is unlikely that all capabilities will reside in a single organization.

An essential feature of a resource-based view is that capabilities and competencies tend to reside in organizations. We have therefore approached the Audit and Review on the basis of understanding the characteristics of organizations that contribute to the STI resource base and the arrangements that are, or could be, put in place to ensure that there is effective cooperation and collaboration between them.

1.4 Methodology And Approach To The Audit And Review

Information about Victoria's STI resource base was collected from people and organizations identified as being involved in science, technology and innovation activity. A copy of the letter requesting information is located in Attachment 1.

The lists of organizations contacted, drawn from the *Australian Technology Directory* and the *Technology Directory of Australia*, are located at Annexes 2, 3 and 4. These lists were supplemented, and corrected, during the review process. This directory information was added to by contacts provided by staff in the Department of State and Regional Development and other sources. This information has been captured in the ***STI Database*** that can be used on an interactive based in Access 2000.

Respondents were asked for information in the form of a submission rather than a response to a questionnaire. Our experience is that questionnaires can miss important contextual information. In addition, respondents often wish to provide information in their own format.

In many cases respondents indicated that they did not have the time or resources to provide the information in the format requested. In these cases we asked for copies of Annual Reports, submissions to the NH&MRC and other documentation that described purpose, activities and achievements. In this respect, we note that many of the Victoria based Health and Medical Research Institutes produce excellent Annual Reports on activities. Copies of Reports and documentation are available in the Department of State and Regional Development STI Library.

It became the role of the Review Team to extract information from the Annual Reports and other documents provided for incorporation into the STI information base. This became a time consuming exercise. We believe, however, that the effort has been worthwhile in that we have been able to produce a comprehensive profile of the capabilities of Victoria's STI resource base.

As part of the Audit and Review, we also undertook detailed analysis of expenditure on Research and Development in Victoria. Data has been analysed by source of funding, fields of research and socio-economic objective. This information provides important background for assessment of STI capability.

1.5 Audit and Review Outputs

In addition to this report, the outputs of the Audit and review are:

- An STI Database
- A *Compendium of STI Organizations Based in Victoria.*

The features of each product are discussed below.

1.5.1 The STI Database

One of the outcomes of the audit is the production of the STI Database. The Database identifies the following resource elements:

- Organizational characteristics
- Facilities and equipment
- Skilled personnel
- Information and knowledge
- Research focus –
  - Field of research
  - Socio-economic objective
  - Capital and funding arrangements.

Respondents were also asked to identify specific gaps in STI resources.

The returns from organizations with details for inclusion in the STI Database were uneven. The coverage of organizations is indicated Table 1.

Table 1: Responses to the STI Request for Information

Organization Category	Number of Requests	Returns Completed	Returns Partially Completed	Response Rate (%)
Companies	396	41	5	12
CSIRO Business Unit	24	12	1	54
Other Commonwealth Organization	12	5	1	50
University Research Centre	206	40	5	22
Medical/Clinical Research Institute	39	17	5	56
Agricultural Research Institute	18	17	0	94
Other State Government Institute	1	1	0	100
Cooperative Research Centre	18	10	1	56
Industry/Professional Association	51	19	2	37
Total	765	162	20	24

More detailed information about which organizations responded to the Request for Information is provided in the Annexes to this report.

The response rate from companies was particularly disappointing. The low response rate from university research centres may be a reflection that some centres are not fully functional or have been disbanded. There was also unevenness in responses from various institutions.

As indicated, the material provided in response to the Request for Information has been included in an Access 2000 Database. The Database can be interrogated for information regarding STI assets and report formats have been prepared. A number of sample reports have been provided to the Department of State and Regional Development.

1.5.2 The *Compendium of STI Organizations Based in Victoria*

Due to a concern about the limited coverage in some sectors of the STI Database, we have drawn together publicly available information about STI organizations. Sources of information include:

- Annual Reports
- Submissions and documentation to support funding applications
- Internet sites.

We have brought the information together in a consistent classification format and common data sets. This data set has greater coverage but less information than the STI Database. However, the data presents an overview of STI resources base that can be accessed on CD ROM in Acrobat or Word 2000 format. The information that is available is presented in a separate Report Volume: *Compendium of STI Organizations Based in Victoria*

1.6 The Structure Of The Report

The Report is presented in four parts:

- Part 1 contains background information and addresses issues concerned with the identification, management and access to STI resources
- Part 2 contains a description of the STI resource base, from an expenditure and organizational perspective
- Part 3 provides information on capacity and capability in specific sectors
- Part 4 contains information about perceived STI gaps provided by organizations that responded to the "Request for Information".
- Six Annexes – containing statistical and supporting material.

In Volume 2, we have provided hard copy of the *Compendium of STI Organizations Based in Victoria*. It contains detailed information about STI capability in the 200 organizations for which we have been able to obtain information. A CD ROM Version of this will be made available.

Volume 3 contains detailed information on expenditure by socio-economic objective and fields of research

1.7 Acknowledgements

We would like to thank the people and organizations who participated in the Audit and Review by provision of information, their hospitality at site visits and their attendance at focus groups.

We would also like to thank the assistance and support of staff in the Department of State and Regional Development STI Unit, particularly John Neve who project managed the assignment.

2 The Audit And Review Framework

The project brief required an “audit” and a “review”. An audit is very much a “stock take” – to identify what exists, its condition and, its capacity and capability for contributing to defined and identified purposes. A stock take also contributes to understanding what is missing and what might be required to ensure that overarching purposes can be achieved.

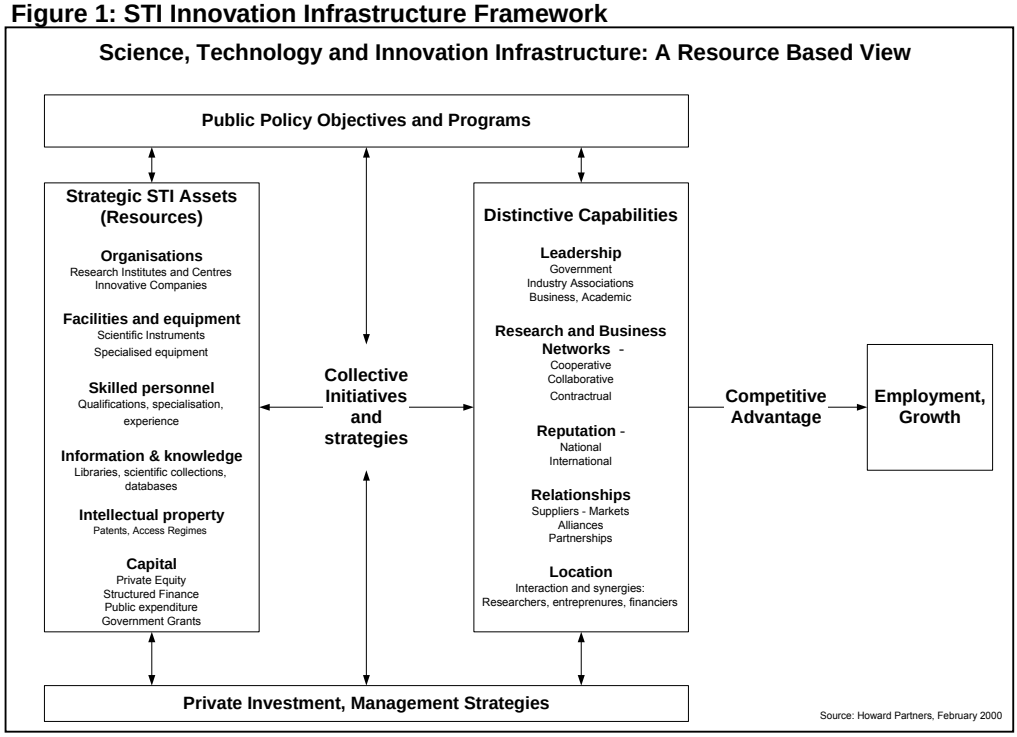
The review component of the project requires assessment, analysis and recommendation for change and improvement. In the context of this assignment, the overarching purpose is to identify STI resources that will contribute to the generation of income and employment in Victoria.

In meeting the terms of reference for the assignment, our objective has been to:

- Identify Victoria’s STI resource base
- Identify where Victoria has "distinctive capabilities"
- Identify where capabilities might be developed through improvement in networks of cooperation and collaboration between the public research sector and industry.

A framework for thinking about these issues was developed during the course of the assignment and is reflected in the following diagnostic. There was general agreement with the framework from the many people consulted during the audit and review process.

Figure 1: STI Innovation Infrastructure Framework



In addition to identifying the organizations that contribute to the Victorian STI resource base, it is also important to understand the operation of research and business networks-particularly those that relate to interactions between them.

3 Defining Science, Technology And Innovation

The Audit and review is focused on science, technology and innovation. It is important to understand the relationships between these elements and, in particular, their contribution to economic growth

3.1 Science and technology

Science is taken to mean systematic and formulated knowledge. Technology can be defined in many ways, but can be interpreted to mean the application of science. Specifically, technology is the application of knowledge in the process of production: it is embedded in knowledge and skills.

It has been argued that technology, as an outgrowth of science, promotes and sustains industrial performance and economic growth. Economic history informs us that technological development and advances have been associated with major advances in industrial development and economic growth.

The nature of the relationship between technological advance and economic growth is, however, quite complex and there is a considerable academic literature on the subject. The relationship reflects a complex interplay of supply as well as demand conditions and a capacity to take technology to the next stage – innovation.

This Audit and Review has identified science and technology activity from a research and development perspective. We were not able to access an acceptable science and technology classification. The Australian Bureau of Statistics classifications of research and development activity by *Socio-Economic Objective [SoE]* and *Fields Of Research [FOR]* have been used.

The socio-economic groupings are intended to reflect the outputs and outcomes of research effort. They are similar to the classifications used in the National Accounts and Government Finance Statistics published by the Bureau. The SoEs that have received attention in Review are:

1. Defence
2. Plant and Animal Production (Primary Industries)
3. Mining and Minerals
4. Energy
5. Manufacturing
6. Construction
7. Transport
8. Information and Communications
9. Commercial Services
10. Health Services
11. Environmental Industries
12. Natural sciences, technologies and engineering.

We have been particularly interested in the research effort that occurs within these areas. The main elements of the fields of research classification in which we have had an interest are:

1. Agricultural sciences
2. Applied science and technologies
3. Biological sciences
4. Chemical sciences
5. Earth sciences
6. Information, computer and communications technologies
7. Mathematical sciences
8. Medical and health sciences
9. Physical sciences

We have not focussed attention on the humanities and behavioural sciences.

3.2 Innovation

Current public sector interest in innovation stems from a general recognition of its importance in promoting and sustaining economic growth. Innovation can be interpreted to mean, quite simply, the supply of "better and more economic goods and services".[2] In a practical sense, innovation can be thought of in the following terms

> Innovation may take the form of a lower price – the form with which the economist has been most concerned, for the simple reason that it is the only one that can be handled by his quantitative tools. But it may also be a new and better product (even at a higher price), a new convenience or the creation of a new want. It may be finding new uses for old products . . .
>
> Innovation goes right through all phases of a business. It may be innovation in design, in product, in marketing techniques. It may be innovation in price or service to a customer. It may be innovation in management organization or management methods.[3]

Innovation is not just a single action – it is *a process* that involves the conception of an idea, invention of a new device/product/service and the development of a new market: it relates to the commercial and practical application of ideas and inventions. Invention is the conception of an idea, whereas innovation is the subsequent translation of an invention into the economy.[4] Thus:

Innovation = Theoretical Conception + Technical Invention + Commercial Exploitation

Within this framework –

- Theoretical conception - New ideas, whilst interesting, exciting and often motivating are merely thoughts or collections of thoughts

  Ideas may stem from a range of sources - from discovery research to perceived gaps in the market

- Technical invention – The process of converting thoughts into a tangible artefact (a product, service or process).

  This is where science and technology may play a significant role

[2] Drucker, P.F., *The Practice of Management*, London: Heinemann, 1955, pp 55-56. Subsequently republished and re-stated in various editions over the last 45 years.
[3] ibid
[4] Trott, Paul, *Innovation Management and New Product Development*, London: Financial Times-Pitman, p.12. This definition draws on a US Department of Commerce analysis.

- Commercial exploitation – Combining inventions into products that will improve company performance – involving the combined efforts of R&D professionals, management and marketers.[5]

Innovation is the *complete process* and requires top management attention, involvement and commitment. For businesses to survive in a competitive environment, they must be continually involved in the process of innovation.[6]

Innovation is *not* confined to engineering or research or to manufacturing businesses alone. It extends right across an organization and through the value chain.

4 Innovation And Organization

4.1 The Importance Of Organization

The resources that are required, in terms of knowledge, skills, facilities, equipment and finance mean that significant innovations are synonymous with organizations. With few exceptions, the more recent innovations and scientific developments are associated with organizations rather than individuals. What is of interest, and important for this study, is the development of *innovative forms of organization* built around cooperative and collaborative arrangements between the universities, publicly funded research organizations and institutes and industry.

In Australia, publicly funded Cooperative Research Centres are important ways of building collaborative arrangements, and there are 27 with a presence in Victoria. There is, however, much more cooperation and collaboration that takes place through various forms and formats, and there is much that can be done to develop and promote organisational cooperation and collaboration. In this area, professional and industry associations, as well as government, have important roles to play.

An organization is a collection of "productive resources" that is managed to achieve particular purposes, results or outcomes. These resources embody a range of distinctive *capabilities* that allow organizations to continue in existence - as well as developing and retaining competitive advantage. An organization's resources include:

- Tangible assets such as buildings, facilities, equipment, property and patentable inventions
- Intangibles, such as brand, image, reputation and human skills.
- Management capacity and capability
- The funds that the organization is able to access.

It is known that the management of innovation creates important challenges in organizations. Much has been written about innovation management *within* organizations, including the creation of the right environment for the development and nurturing of ideas from conception through to market.[7] Importance is attached to "organic" forms of organization that stress teamwork, collaboration and acceptance of a certain degree of uncertainty and ambiguity. These considerations are equally important to relationships *between* organizations.

[5] Ibid
[6] Management theory suggests that there are two main purposes of a business: to create a customer and to continuously innovate.
[7] One of the earliest, and most significant contributions in this area is by Tom Burns and G.M. Stalker, *The Management of Innovation*, first published in 1961 and republished in a revised edition by Oxford University Press in 1994

The emergence of collaborative relationships between organizations also involves some element of management and organization structure. *Increasingly, "organization" is being understood in a framework that is broader than the legal boundaries of a company.*

Recommendation

> **The Victorian Science, Technology and Innovation resource base be thought of in terms of capabilities that exist in a network of firms and organizations that have distinctive capabilities and which interact, to a greater or lesser degree, through processes of cooperation and collaboration – as well as competition.**

These collaborative arrangements exist in the following forms of organization:

- Publicly funded research organizations
- University research centres
- Commonwealth funded Cooperative Research Centres
- University backed commercialisation ventures.

4.2 Cooperation, collaboration and networks

In the current environment the concept of the individual inventor or research laboratory achieving commercial success on the basis of one activity, and without expert management, marketing and substantial ongoing financial support, is a misrepresentation of the nature of innovation. Innovation requires cooperation and collaboration *within* an organization as well as with organizations external to it.

The form of collaboration and interaction between organizations is becoming increasingly important in the context of globalisation, the cost and complexity of research and development, and the importance of supply and distribution channels. The commercialisation of invention that occurs through collaboration between research organizations, research centres and businesses is of particular interest in this Review.

In a number of industry sectors, a network of relationships with other organizations is a major criterion for success in competitive markets. These relationships cover supply, distribution and marketing – and increasingly, research and development. Research and development is now extensively outsourced to specialized organizations, including universities and research centres, under various forms of alliance arrangement. *Companies wish to tap into richer innovation skills that outside suppliers can offer.*

Business is being conducted through complex interlocking clusters, groups and alliances that represent fully and formally developed systems of cooperation and collaboration. These "clusters" may be geographically based – or be based on a broader concept of "community of purpose".

It is also recognized that networks of relationships between firms and organizations are essential where

- More is derived for an organization than "going it alone"
- Strategic competencies and capabilities are augmented
- Strategic flexibility is retained
- Competencies/capabilities are not "appropriated" by a partner or collaborator.

In the context of research and development, collaborative arrangements allow for different organizational forms to co-exist: for example, the "organic" structure of a research team with the formal authority and control structures of a large corporation or a university department. A number of large organizations have "spun out" their research departments with the specific purpose of allowing for the different organizational forms to continue and co-exist. There are also situations where research and development capability has been "spun out" from university departments to create a greater focus on the market and commercial imperatives.

4.3 Forms of interaction, collaboration and cooperation

Trends in the public funding of higher education, new approaches to R&D management within corporations, a changing culture of learning, and the growth in small service and high technology industries, has led to the emergence of new forms of research that require close working relationships between people located in different institutions – not all of whom need be scientists. It has been observed that:

> . . . there are formally designed interactions of university-based researchers with business people, venture capitalists, patent lawyers, production engineers, as well a research engineers located outside the university. This invariably involved shared use of academic and industrial facilities. Under these conditions, technology, is more likely to be trans disciplinary, and to be carried out by people who are able to rise above disciplinary and institutional loyalties.
>
> These and similar changes and transformations are advancing so rapidly that their impact on traditional institutions and attitudes has just begun to be understood.[8]

Changes in the organisational arrangements are also having an impact on funding arrangements. Public funding from government programs is increasingly being supplemented and/or replaced by firms, industries and industry associations representing a group of firms..

The cooperative and collaborative relationships between universities, research organizations and industry can be considered in terms of a spectrum that ranges from unconditional financial flows to highly structured corporate arrangements in the form of joint business ventures. These are summarized In Table 2.[9]

Table 2: Forms of Interaction between Research Organizations and Industry

Form of interaction	Nature of the Interaction	Features
Corporate gifts and bequests	Business makes funds available as an act of "corporate citizenship". This may involve naming of a Facility, Chair, building, scholarship, prize or award	Recent changes to the capital gains tax arrangements will facilitate an increase in the flow of corporate bequests A number of medical research institutes rely heavily on bequests from trusts and family estates.

[8] Ganguly, Ashok, *Business Driven Research and Development: Managing Knowledge to Create Wealth,* London: Macmillan, p. 33.

[9] Chart developed for inclusion in the background report for the Australian research Council on University-Industry Interaction.

Form of interaction	Nature of the Interaction	Features
Corporate Sponsorship	Businesses invited to contribute funds to support a teaching and research centre or institute through "membership". Grades of membership might also be offered Business may have option to collaborate on further research. The mechanism is similar to sponsorship of a cultural institution	Business benefits from its name associated with the research effort and the networking opportunities Business has no involvement in setting directions or priorities, although may be invited to be a member of Faculty or a Board Corporate Sponsorship also involves supporting staff to undertake post-graduate research There may be tax benefits associated with sponsorship
Cooperation	Working to achieve a common end with a strong collective benefit There is a focus on creating and applying new knowledge Interaction tends to be on a program basis	A specific entity may be established to manage the process and "own" the outcomes Funding on a "contribution" basis Business participates in the management of the program
Collaboration	Working to resolve a specific problem to achieve a business outcome using and applying existing knowledge Interaction is on a project basis	Business participates in the design and management of the project on a "partnership" basis Funding on the basis of an agreed budget and commitment
Contract	Working to achieve specific "business" ends – for a specific outcome or a process for transferring knowledge	Business specifies an outcome and pays a specific fee for service Funding on the basis of a contract
Community	Scientists and research professionals interact through a system of shared values	Informal interaction through understanding and commitment to a shared goal
Commercial Participation	University and research organization staff participate as expert advisers to business – as Board members or special advisers	Substantial benefits may be derived from having an expert "academic" as a Board member
Commercial Partnership	University seeking to commercialise aspects of capability through joint ventures with business in the form of spin-off companies Other areas include short courses, conferences and seminars with business sharing the risk, to make money for a faculty and/or academics	Business contributes funds through equity investment Business may accept part or all of the risk in the venture May be an industry association involved
Competitive Commercial	Working to achieve a financial return from a business enterprise in competition with existing businesses Covers aspects of consultancy, continuing education, conferences and training	Universities and research organizations operate in competition with business for the provision of products and services Competitive neutrality a major concern

All of these relationships exist within the Victorian STI institutional framework and make a very important contribution to the resource base. They are reflected in:

- Research Foundations
- Cooperative Research Centres
- University Research Centres
- Joint Ventures
- Start-up and spin-off companies.

These arrangements are discussed in Part 2.

5 Conclusion

Our approach to the assignment has been based on a view that STI resources exist in organizations – either in the public or private sector. Organizations not only own or possess tangible assets and explicit knowledge – such as facilities, equipment and patents, they also provide a working environment for individuals who have knowledge, skill and experience used in the generation and application of specific capabilities.

An organisational perspective recognises that innovation mostly occurs in an organisational context. While individual inventors, acting alone make important contributions, the reality is that most innovation occurs in situations where there are substantial capabilities for research and development, management of resources and for understanding markets and consumer preferences. Organizations also provide the supportive infrastructure for a working environment – including the physical systems used to store and transmit intellectual material.

We take a broad view of organizations: they can be formal, in a hierarchical context, with clearly defined boundaries, or they can be informal, built around networks and alliances. Networks and alliances, based on cooperation and collaboration, are becoming increasingly important in the knowledge economy. What is of interest in the Review are the *capabilities* of the organizations, both formal and informal, that make up the Victorian STI resource base. This issue is addressed below.

In the current economic development environment, it can be argued that Victoria's potential depends not so much on its location and STI resources but on its human will, skill, energy, values and organizational capabilities – including the capacity to enter into collaborative arrangements and support the operation of networks.

The networks and forms of interaction are important components of the Victorian STI base. Resources and capabilities that exist alone in research and business organizations are of greater significance when seen in the context of cooperative and collaborative arrangements. These arrangements exist, in large measure in research centres and institutes – some of which receive government funding – and in other forms of formal and informal interaction between government, business and the research community.

A number of points have already been made about strengthening Victoria's STI base that have specific relevance to a cluster focus. These include strategic investments in facilities and equipment, developing people and knowledge and information dissemination.

In the discussion of organizations, reference is being made to a wide range of entities – including companies, government agencies and university based research centres. This discussion is pursued in the next section.

Part 2: The Victorian STI Resource Base

1 Introduction

The purpose of this Part of the report is to address those matters in the project brief that sought comments in relation to:

- The relationship between access to key infrastructure and the ability of the organization or user organizations to attract/maintain key personnel, research programs and research funding
- Clustering of activity around key infrastructure installations - including (but not limited to) Clayton, Parkville, and Fishermans Bend and around the Alfred Hospital
- Mechanisms to update information on Victorian STI research infrastructure in a cost effective manner.

To address these issues it is necessary to comprehend the scope and scale of research infrastructure capability and investment in Victoria. This is done by drawing attention to the organizations and organization characteristics of research performers in the State. Attention is also drawn to the mechanisms for sourcing funds for STI investment, particularly in relation to sourcing funds for innovation – taking technological invention through to commercial exploitation.

Victoria's STI capability is located in a diverse range of organizations. As indicated in Part 1, these capabilities include:

- Machinery and equipment
- Knowledge of technology
- Skilled personnel
- Intellectual property
- Organization and management competencies
- Access to funding for commercial application.

The way in which organizations develop and access these capabilities is of particular importance in this review. We have argued that, increasingly, STI capability is developed on a collaborative and cooperative basis between a number of organizations in a variety of arrangements.

Information on the level of R&D investment in STI research and output areas is provided in Annex 5 at the end of this Report. We acknowledge that expenditure on research and development is at best a proxy indicator of commitment to innovation and growth. What really matters, of course, is the *effectiveness* of R&D investment – which depends, in turn, on integrating research and development with business, marketing and customer strategies and, above all, the quality of innovation management.

Reference has already been made in Part 1 to the concept of science clusters. We have argued that *cooperation, collaboration and networking* are critical for developing and sustaining the STI resource base. Geographic clustering may, but equally may not, be associated with significant innovation. Material is provided which provides an indication of the degree of collaboration and interaction between large corporate R&D performers and the research community.

For the purposes of discussion and review, organizations are identified under the following categories:

- Commonwealth research performing agencies located in Victoria
- State research performing organizations
- Universities

- Cooperative Research Centres
- University Research Centres
- Established companies with a significant commitment to research and development
- Innovative companies

Many of these organizations have provided information concerning capabilities and STI assets for inclusion in the STI Database. The Review Team also collected information from publicly available sources for a large number of organizations that did not respond to our "Request for Information". This information is included in *The Compendium of STI Organizations Based in Victoria.*

2 Commonwealth Government Research Performing Organizations Located in Victoria

2.1 CSIRO

The CSIRO is a national organization, with a presence in all States and Territories. There is, however, a substantial capability in Victoria. The Organization invests $2.1 billion every three years - about 70% directly through the Commonwealth Government.

CSIRO provides independent expert advice to policy-makers in governments and companies and is a key resource for major Government R&D programs and for innovative companies. It has strong international links which mean that Australia keeps pace with scientific developments around the world. These linkages also help to underpin Australia's regional interests.

There are 17 CSIRO business units with a substantial presence in Victoria.

- Animal Health
- Atmospheric Research
- Australian Automotive Technology Centre (A wholly owned subsidiary of CSIRO)
- Building, Construction and Engineering
- Food Science Australia (A Joint Venture between the CSIRO and the Australian Food Science Centre
- Forest Products
- Health and Nutrition
- High Performance Computing and Communications Centre.
- Manufacturing Science and Technology
- Mathematical and Information Sciences
- Minerals
- Molecular Science
- Petroleum Resources
- Plant Industry – Horticulture Unit, Merebin
- Telecommunications and Industrial Physics
- Textile and Fibre Technology

Further discussion of the STI capability these Business Units is contained in Part 3 of this Report and in the STI Data Base and the *Compendium of STI Organizations in Victoria*.

2.2 Bureau of Meteorology

The Bureau maintains a substantial research and development capability in Melbourne in atmospheric research.

The overall mission of the Bureau is to observe and understand Australian weather and climate and provide meteorological, hydrological and oceanographic services in support of Australia's national needs and international obligations. This overall mission involves four separate basic missions:

- Monitoring - observation and data collection to meet the needs of future generations for reliable homogeneous national climatological data;
- Research - research directed to the advancement of meteorological science and the development of a comprehensive description and scientific understanding of Australia's weather and climate;
- Services - provision of meteorological and related data, information, forecast, warning, investigation and advisory services on a national basis; and
- International -coordination of Australia's involvement in international meteorology.

The Bureau collaborates with the CSIRO in the High Performance Computing Centre. Information about capacity and capability is contained in the STI Information base.

2.3 Defence Science and Technology Organization

The DSTO Aeronautical and Maritime Research Laboratories are located in Melbourne. The capability covers

- Air operations
- Airframes and engines
- Combat protection and nutrition
- Maritime platforms
- Theatre operations group

The AMRL is located at Fisherman’s Bend. It provided a consolidated input into the STI Information base.

3 State Government Organizations

The most significant components of the Victorian Government commitment to the STI base occur through the Research Institutes of the Agriculture Victoria (A Division of the Department of Natural Resources and Environment) and the Public Hospital System. A significant amount of research and development effort occurs in VicRoads as well as in the corporatised utility companies.

3.1 Agriculture Victoria

The Department of Natural Resources and Environment has 16 Research Institutes spread across the State. The Institutes cover a broad range of areas from sustainable production systems, pastures and crops, fisheries, pest control, and food processing, to forest use and conservation. The Institutes are listed below with a short list of research foci.

- Arther Rylah Institute for Environmental Research

- Centre for Land Protection Research
- Centre for Tree Technology
- EllinbankDairy
- Institute for Horticultural Development
- Institute for Integrated Agricultural Development
- Institute of Sustainable Irrigated Agriculture
- Keith Turnbull Research Institute
- Marine and Freshwater Resources Institute (MAFRI)
- Ovens Research Station
- Pastoral and Veterinary Institute
- Plant Biotechnology Centre
- State Chemistry Laboratory
- Sunraysia Horticultural Institute
- Victorian Institute of Animal Science
- Victorian Institute of Dryalnd Agriculture

Agriculture Victoria has provided a large amount of detailed information about resources and capability in a comprehensive return. That material is in the STI Information base.

3.2 Victorian Hospitals

The Victorian hospital system contains a substantial STI resource base and research capability. These occur in the major teaching hospitals, including:

- The Alfred Hospital
- Austin and Repatriation Medical Centre
- Monash Medical Centre
- Royal Melbourne Hospital
- Royal Women's Hospital
- Royal Children's hospital
- St Vincent's Hospital

Most of these organizations have affiliations with specialised medical and clinical research institutes and with Universities. Information is included in those categorisations in the STI Database and in *The Compendium of STI Organizations in Victoria.*

3.3 Other State Government Agencies

The following State Government Agencies provided input into the Audit and Review:

- The Museum of Victoria
- The Royal Botanical Gardens
- Vic Roads

4 Hospital Based, Government and Independent Medical and Clinical Research Institutes

There is a large number of medical and clinical research institutes in Victoria that receive funding from the National Health and Medical Research Council, sponsorship and benefactions as well as grants from overseas research funding bodies. These include:

- Arthritis Foundation of Victoria Centre for Rheumatic Diseases
- Austin Research Institute
- Austin and Repatriation Medical Centre
- Australian Genome Research Facility

- Baker Medical Research Institute
- Bernard O'Brien Institute of Microsurgery
- Bionic Ear Institute
- Bimolecular Research Institute
- Centre For Behavioural Research In Cancer
- Centre for Developmental Cancer Therapeutics
- The Centre for Early Human Development/Animal Gene Storage and Resource Centre of Australia
- Howard Florey Institute of Experimental Physiology and Medicine
- Heart Research Centre
- Institute for Drug Technologies
- Institute for Reproduction and Development
- Ludwig Institute for Cancer Research
- Macfarlane Burnett Centre for Medical Research
- Mental Health Research Institute of Victoria
- Murdoch Institute for Research into Birth Defects
- Mutation Research Centre
- National Aging Research Institute
- Parkville Bioinformatics Consortium
- Peter MacCallum Cancer Institute
- Prince Henry's Institute of Medical Research
- Royal Children's Hospital Research Institute
- St Vincent's Institute of Medical Research
- Victorian Breast cancer Consortium
- Victorian Breast cancer Initiative
- Walter & Eliza Hall Institute of Medical Research

Most of these Institutes are constituted as independent entities with their own boards and corporate identity. A number have been established on the basis of private benefaction and sponsorship. Victoria is somewhat unique in having such an extensive range of capability in these organizations.

The Institutes retain close relationships with University medical and clinical departments and with Teaching Hospitals. Many of the senior staff have academic appointments and carry academic titles.

Detailed information about the operations and contribution of the medical research institutes to the STI resource base is included in the STI Database and The *Compendium of STI Organizations in Victoria.* Many of the Institutes provided information for the Audit and Review. However, in many cases that information was provided in the form of an Annual Report only. In some cases the Review Team obtained the information directly from other sources – such as the Internet. Institutes may have the opportunity to update information in subsequent revisions to the STI Database and *Compendium of STI Organizations in Victoria*.

5 University Linked Organizations

5.1 Universities

Victoria has eight Universities. Three of those evolved from Colleges of Advanced Education and Institutes of Technology and to a large extent retain a very strong technology focus. There is a substantial STI research capability within all University

departments and faculties as well as in the specialised research centres and institutes attached to the universities.

The traditional perception of universities is that of teaching and "discovery research". To that end, their involvement in the STI framework would be limited. However, universities are becoming much more involved in "problem driven" research. This development has been associated with greater collaboration with industry and the development of trans- and interdisciplinary approaches to scientific inquiry.

For example, it was largely industry that saw the emergence of new business opportunities emerging following the insights into DNA and the silicon chip driven growth fuelled by the computer industry. The consequence of these developments has been a new way of generating, managing and exploiting knowledge with significant implications for the STI base. Moreover, in an American context, but increasingly relevant to Australia:

> Because the emergence of this new way of working had not been clearly foreseen or visualized and did not quite fit the linear management models of the day, the creation of trans- and interdisciplinary science clusters, which were task or sector specific, evolved more or less by trial and error. [10]

In this context, science and technology clusters represent "utilizable entities of fundamental knowledge flowing in from a critical mass of related scientific research"[11]. Science clusters are often firm specific and need not be limited by geography: they are defined in terms of the interactions and relationships of scientists and their respective fields of expertise. With information technology, such clusters may reflect a combination of regional, national and international dimensions.

At the same time, however, a science and technology cluster may be seen in a geographic sense where separate institutions, in combination and collaboration, build a critical mass of utilisable knowledge. This can be observed in areas such as molecular biology, a field of inquiry that has evolved as a result of the way questions are framed and research undertaken in immunology, genetics and cell biology across a number of organizations. In Melbourne, the universities, the CSIRO and the medical research institutes have a very strong capability in this area. It is also an area that is of intense interest to companies.

There is probably more to be done, however, in promoting collaboration and cooperation between scientists and attracting and sustaining corporate interest and involvement.[12] Glaxco Wellcome advised the review team that

> The lack of collaboration between scientists and institutions is a major disadvantage in innovation in drug discovery in Australia. The competitive process and the low rate of funding for projects are disincentives for collaboration. Vertical collaboration between multi-disciplinary sciences is critical in drug discovery.
>
> To develop the capability of drug development, scientists will have to work together in a multi-disciplinary approach. In the future, innovation in medical research will come from discoveries in genetics and identification of new targets for drug design. These opportunities will be achieved through close working relationships between geneticists, molecular biologists, chemists, pharmacologists, toxicologists and clinicians.

[10] Ganguly, Ashok, op. cit. p. 37
[11] Ibid
[12] There is only one major corporation involved in the Parkville area of Melbourne.

This observation was repeated in a similar vein on a number of discussions and consultations throughout the review process.

5.2 Cooperative Research Centres

A recent assessment of science and technology management[13] has emphasised that important changes are taking place in the relationship between universities, research institutions and industry R&D departments. In particular:

> The emergence of new university-industry partnerships, by academics working on industry R&D projects in formal and joint teams, is replacing the traditional donor-recipient contracts and relations between academia and industry. Well planed access to appropriate academic centres, which are generators of knowledge, through a network of project partnerships, is turning out to be the only cost effective method for a firm to sustain a critical mass of leading edge R&D capability. [14]

University-business collaborative partnerships emerged in the agriculture sector, and still have an important role in the Victorian agricultural research institutes. More recently, partnerships have received further impetus by the spread of venture capitalism which has "given a whole new meaning to risk taking and entrepreneurship[15]. Australian venture capitalists are becoming much more involved in university-business-finance partnerships[16].

In Australia, government supported Cooperative Research Centres have developed as important organisational forms that facilitate university-industry collaboration. The are collaborative research and education ventures which seek to develop strategic linkages between researchers and research users, particularly industry. The program commenced in 1990. CRCs have a focus on:

- Research, research training, education and commercialisation
- Basic, strategic and applied research and development

The Program supports research with a primary focus on the natural sciences and engineering and their application. It is recognised that the work of many CRCs will be multi-disciplinary and may involve contributions from other areas

There are 22 Centres with formal structured arrangements with Victoria's eight Universities. They have built on existing, but less formal research linkages and have become important centres for postgraduate research. They have also played an important role in changing research cultures in both industry and academic research groups. The centres are listed below.

- Australian Geodynamics CRC
- Australian Maritime Engineering CRC
- Australian Photonics CRC
- Australian Telecommunications CRC
- CRC for Advanced Composite Structures
- CRC for Bioproducts
- CRC for CAST Metals Manufacturing
- CRC for Catchment Hydrology

[13] Ganguly, Ashok, *Business-driven Research and Development: Managing Knowledge to Create Wealth,* London: Macmillan, 1999. Dr Ganguly was director, worldwide, for seven years at Unilever.
[14] Ibid, p. 5.
[15] Ibid.
[16] A recent example of such a partnership is the commercialization progress of the Australian Photonics CRC.

- CRC for Clean Power from Lignite
- CRC for Enterprise Distributed Systems Technology
- CRC for Freshwater Ecology
- CRC for Hardwood Fibre and Paper Science
- CRC for Intelligent Manufacturing Systems and Technologies
- CRC for International Food Manufacture and Packaging Science
- CRC for Micro Technology
- CRC for Molecular Plant Breeding
- CRC for Polymers
- CRC for Sensor Signal and Information Processing
- CRC for Southern Hemisphere Meteorology
- CRC for Viticulture
- CRC for Water Quality and Treatment
- GK Williams CRC for Extractive Metallurgy

Further information about their operations and research program is provided in Part 3 of this Report and in the STI Database and the *Compendium of STI Organizations in Victoria.* Where CRCs did not provide information to the Review Team, material has been sourced from Reports and the Internet.

5.3 University Research Centres

5.3.1 Trends and Growth

There is an extensive network of research centres and cooperative arrangements within the Victorian science, technology and innovation sector. Research centres have emerged as a response to a need for strength and diversity in university-industry interaction linked to formal university research strategies - reflected in annual "research management plans"[17] There are approximately 120 research centres identified in the Victorian higher education system, depending on sources and definitions

Centres often by-pass University funding arrangements by drawing on industry and government contracts. Most research centres have strong industry linkages – in terms of sponsorship, collaboration and contract. A number provide the university linkage to a Cooperative Research Centre. Research Centres provide a focus for integration of different modes of university-industry interaction – eg PhD programs, short course delivery, industry training and consulting. A number of centres receive ARC funding as "key research centres" and as special research centres.

Whereas the Cooperative Research Centres focus on government supported, multi-partner, collaborative research, Research Centres are tending to focus on dedicated partnership research programs, without government underwriting. It has been argued that dedicated partnership research programs tend to be much more productive and longer lasting - provided of course they are managed competently and fairly.[18]

In undertaking the Audit and Review, we contacted a total of 206 centres, as identified in the Science and Technology Directories, and received 40 responses. To obtain more information about Centre activities, the Team sourced information published on websites. Centres that did not respond to the "Request for Information" or which did not have easily accessible Internet websites containing information that could be used in the Audit and

[17] DETYA, 1996
[18] Ganguly, op.cit. p.35

Review, are not included in the STI Database or the *Compendium of STI Organizations in Victoria*

The information sourced from the Internet has not been validated with relevant centres. These centres and those that did not respond may have an opportunity to provide information in updates to the STI Database and subsequent editions of the *Compendium of STI Organizations in Victoria.*

The number of centres covered in the Audit and Review, classified in terms of Socio Economic Objective, is listed in below. The classification by SoE is indicative, but does serve to indicate the concentration of collaborative research effort.

Research Centres Classified by Socio Economic Objective

Socio-Economic Objective	Number of Centres
Defence	0
Plant and Animal Production (Primary Industries)	12
Mining and Minerals	4
Energy	3
Manufacturing	23
Construction	0
Transport	3
Information and Communications	25
Commercial Services	0
Health Services	35
Environmental Industries	8
Natural sciences, technologies and engineering.	9
	122

The classification points to a heavy concentration of collaborative research effort in plant and animal production, manufacturing, information and communications and health services. It is in these areas that there are strong university industry partnerships.

This information concerning research concentration on an organisational basis is confirmed by the expenditure data provided in Section 5.

5.3.2 Scope of capability

The extent and coverage of research centres and institutes points to a substantial resource and organisational commitment. Potentially, there may be scope for greater efficiency and concentration of research effort if entities collaborate in seeking available funding and support. If, however, each centre is distinctive in terms of its capacity and capability, *and* the networks for cooperation and collaboration between centres and institutions are working, then the organisational infrastructure can provide a sound basis for developing Victoria's STI base.

In this respect, Professor Robert Cotton of the Mutation Research Centre has pointed out that[19]:

> Victoria's medical research effort is spread through a significant number of research institutes located throughout the metropolitan area. Under such circumstances collaborative effort is not easily facilitated and researchers may tend to work in greater isolation than need be the case.

[19] Mutation research center, Submission

> If Victoria is to generate world competitive biological research and development it will only be achieved through interactive collaborations clustered around sophisticated equipment and a high quality shared infrastructure.

Most of these research organizations have provided detailed information for the STI Information base. Some centres, but by no means all, have web sites. Where web sites are maintained, there is a great deal of useful information about resources, capacity and capability. Unfortunately, it is sometimes difficult to access, and it is certainly time consuming. As we have suggested earlier, the development of networks requires some form of organisational and management input – such input must emphasis the management capacities of leadership and facilitation, as distinct from control and direction.

It is also apparent that the emergence of potential for greater cooperation, collaboration and partnership between universities and business, on the basis of knowledge capability, has not been accompanied by formal institutional mechanisms to train managers and equip them to manage large R&D projects and multi-party, multi-disciplinary, collaborative programs. US experience is that the vital elements of extracting synergies and exploring potential value generation tend to be missing.

5.3.3 Accessing information about capacity and capability

The extent of capability in research centres, as well as in Universities makes it difficult to access up to date, relevant and accurate information about capability and performance. Throughout the Audit and Review process, people pointed to this difficulty and the need for a mechanism to ensure that information about capability and contacts was more widely disseminated.

Although many people are adept users of the Internet, many would be deterred, as it is often slow and cumbersome in accessing relevant and authoritative information from the large amount of unstructured data of variable quality, authority and stability. Information is recorded in a variety of formats and contexts – and it is often difficult to discern the actual *purpose* of a particular centre.

It follows that an important issue in this project is to create an awareness and understanding among users about how to access and retrieve information from the Internet *and* other sources. This is an important role for the Department of State and Regional Development acting either on its own behalf or contracting with a third party.

Awareness strategies should communicate the role of the Department as a *knowledge centre* that can add value through filtering and packaging reliable information, *in all formats*, for users. This would include the specialized information provided from primary sources as well as referral to its own material.

One way of achieving this outcome would be to provide *subject "gateways"* on the Internet/Intranet as a single focal point for providing access to information of all kinds for a particular area of STI interest and concern. Gateways would cover print as well as electronic resources.

Gateways could provide linkages to electronic publications, databases, research projects, conferences and research institutes. Each site included in a Gateway could be evaluated, described, classified and indexed. Gateways could be developed to suit the information needs and requirements of specific categories of users in each of the user

segments identified above. We do not see this as a "technical" approach or involving the addition of new services.

The purpose of the Information base developed in this assignment is to facilitate access to and identification of STI resources and capability. However, the Information base will only be useful as long as it is maintained. It was our experience during the review that the science and technology databases that are available have substantial inaccuracies including errors and simply being out of date.

The Information base can provide the foundation for a "Gateway" for STI users.

In our view, it should be the responsibility of the Department of State and Regional Development to sponsor the development of a Gateway and continually update the database as a contribution to facilitating the development and operation of collaborative and cooperative networks in the State.

Recommendation

> **The STI Information base developed in this project provides the foundation for the development of an STI information Gateway. The Information base be continually updated by the Department of State and Regional Development as a contribution to facilitating the development of networks of cooperation and collaboration.**

5.4 University Sponsored Commercial ventures

5.4.1 University commercialisation companies

Universities, through their commercialisation arms, and other arrangements support the commercialisation of research outcomes from within their universities. The main role of the commercialisation arms is to license technology and, if appropriate, market technologies through spin-out companies established for that purpose. Some are involved in further development of their research and have received assistance under other programs (R&D Start, for example)

Monash and Melbourne Universities have companies that are involved in the licensing of IP and the establishment of companies to develop and market technologies. Montech has been established for some time while MEI has been created recently following a review of Melbourne University's IP and technology licensing activities. Other universities are involved in commercialisation through their research offices.

Information on University Commercialisation companies and offices is provided in Volume 2.

5.4.2 Joint venture companies

Recent developments point to the significance of arrangements between universities, business and venture capitalists. Following US experience, some universities seek to derive more income from equity injection and subsequent sale or listing rather than direct licensing of a company. Equity decisions tend to be taken by the university rather than the university commercialisation/technology licensing company.

5.4.3 Consultancy arrangements

A number of universities in Australia through their commercial companies provide expert opinion and consulting and other services to industry. Some are now strong commercial entities earning substantial incomes for their tertiary institutions

These businesses have become part of the professional services sector offering services to industry including research commercialisation, intellectual property development and marketing, commercial market planning and research, general consulting services, product testing, continuing education and exports of commercial services

There is also a group of academic "consultants", who undertake often regular assignments outside the university commercial companies and in competition with commercially based professional services firms. Income is used to supplement academic salaries

6 Geographic Clusters

The Project Brief required that specific attention be given to the "clustering" of activity in a number of areas of Melbourne. The existence of clusters is of interest from a geographic point of view, but the implications for industry policy, including STI strategy, are not clear cut. Of particular interest is the unit of analysis, that is the "size" of a cluster in relation to possible economic benefits.

For these reasons we have provided some background and addressed issues in reflation to clusters in the Victorian STI context.

6.1 Background

Geographic clustering is the subject of a great deal of attention in the current industry policy environment. This is because clusters are seen as playing an important role in the global competitive environment on the basis that enduring competitive advantage is seen to lie increasingly in local things, and in particular, knowledge, relationships and motivation that distant rivals cannot match. Clusters provide a category of resources that are internal to a region, but external to any particular firm or organization.

Clusters build *depth* of skill, capability and competency and an ability to respond to demands for quality, consistency and continuity. This may be referred to as critical mass. Depth might be built by organizations acting alone in a competitive situation, but it is more likely that it will be developed by organizations acting collaboratively in non-market arrangements. These arrangements involve *sharing of resources* through partnerships, alliances, joint ventures, etc. This issue is addressed again below.

Clusters include government institutions, universities, standard setting agencies, think tanks, vocational training providers, and trade associations that provide specialised training, education, information, research and technical support. The linkages and complementarities define boundaries across industries and institutions that are most important to competition. From an international perspective clusters tend to be identified as cities or States rather than specific precincts.

Spatial asymmetries in resources, including natural resources, skills, knowledge, and industry specific expertise have been an important dimension of location theory for some time. What is attracting current attention, in the context of thinking about the "knowledge

economy", is the idea that *industry specific knowledge* becomes cumulative and embedded in a particular *region or area* rather a specific firm.[20] *However, this attribute can only be significant if knowledge can be created, shared and communicated uniquely within the cluster arrangement.*

Cluster analysts argue that information and knowledge become embedded within a region when regional resources become difficult to replicate and imitate in other areas. This depends on historical conditions, the existence of tacit, complex and specific knowledge that is unique to the region, the social interaction of the participants and the openness of communication.[21] Silicon Valley is probably the exemplar of this situation – and is in many respects a special and unique case.[22] It is also difficult to replicate.

Potentially, clusters allow participants to benefit *as if* they had greater scale or *as if* they had joined with others formally – without being required to sacrifice flexibility. They impact on competition through:

- Increasing the productivity of companies based in the area through factors such as:
  - Access to suppliers
  - Complementarities
  - Access to institutions and public goods
  - Motivation and measurement
- Driving the direction and pace of innovation – which underpins future productivity growth
- Stimulating the formation of new businesses, which expands and strengthens the cluster itself.

Michael Porter argues that clusters reveal the mutual dependence and collective responsibility of business, research organizations and government for creating the conditions of productive competition. He suggests that the development task requires fresh thinking on the part of leaders and the willingness to abandon the traditional premises that drive thinking about who does what in the economy.[23] In particular, there is a blurring of the lines between public and private investment –

- Companies, no less than universities, have a stake in education
- Universities have a stake in the competitiveness of local businesses
- Governments can achieve a great deal through information dissemination rather than through public expenditure.

These lines of thought are apparent in the Victorian context. University sponsored and supported technology parks are an example of providing support for local businesses, as is the availability of advisory and consulting services. Regional economic development strategies invariably have strong university input.

More significantly, however, is the strong tradition of collaboration and support provided by government through universities (previously institutes of technology and agricultural

[20] Enright, M.J., Regional Clusters and Firm Strategy, Chandler, Alfred D. et al.(eds), The Dynamic Firm: The Role of Technology, Strategy, Organizations and Regions, Oxford: Oxford University Press, 1999, p.322
[21] Ibid, pp. 322-323
[22] See Saxenian, Annalee, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Cambridge, Mass: Harvard University Press, 1994. Saxenian makes the point that Silicon Valley is unique in terms of the extent of collaboration between universities, entrepreneurs, corporate research laboratories, and venture capitalists, the communication networks and the freedom of communication.
[23] Porter, Michael, *On Competition*, Boston: Harvard Business School Press.

colleges) to industry. This tradition continues through the many University Centres. This aspect of the Victorian STI base is addressed in part 2.

6.2 Clusters in the Victorian STI Context

6.2.1 Parkville

Parkville is the location for:

- The University of Melbourne
- Three of the four block funded medical research institutes located in Melbourne
- The Royal Melbourne Hospital
- The CSIRO Division of Molecular Science
- The CRC for Cellular Growth Factors and CRC for Industrial Plant Polymers
- Other medical research centres, including:
  - Australasian Society for Immunology Inc
  - Centre for Animal Biotechnology
  - Centre for Equine Virology
  - Centre for Hormone Research
  - Glycoscience Group
  - Howard Florey Institute of Experimental Physiology & Medicine
  - Mental Health Research Institute of Victoria Inc
  - Micro-Analytical Research Centre
  - Plant Cell Biology Research Centre
  - The Biomolecular Research Institute Limited
  - The Murdoch Institute
  - World Health Organisation Collaborating Centre for Influenza
- CSL Limited

The Victorian government is currently examining a proposal for a substantial investment in physical infrastructure to support increased capacity in medical research through the Bio21 initiative.

According to the concept plan for Bio 21, the Parkville precinct has the potential to become a major international player in genome science and biotechnology. It is seen to have:

- A rich tradition in biomedical and clinical research and post graduate training that draws international researchers
- A research culture that is receptive to enhancing commercial development activity.

The focus of the precinct is very much on medical research and health services delivery. It does not provide a base for a significant number of companies involved in the commercialisation of new technologies.

CSL is the only biotechnology company currently located in the precinct. The Bio 21 initiative would provide incubator facilities for start-up companies and seek to attract commercial biotechnology R&D.

Bio 21 would be competing with biotechnology parks adjacent to universities and research institutes around the world. Information about the Virginia Bio Research Park can be obtained form http://www.vabiotech.com/ and the Massachusetts Biomedical Initiatives (MBI) from http://www.massbiomed.org/. These initiatives have received substantial private and public support,

6.2.2 The Clayton Area

There is an STI capability centred in and around Monash University and the CSIRO.

Medical and Clinical research based capability includes:

- Centre for Agricultural Biotechnology
- Centre for Biomedical Engineering
- Centre for Bioprocess Technology
- Centre for Human Bioethics
- Institute of Reproduction & Development
- Monash University Centre for Biomedical Engineering
- Neuropsychology Research Unit
- Neurosciences Group
- Prince Henry's Institute of Medical Research
- The Institute for Reproduction ad Development
- The Monash Medical Centre

There is also a strong manufacturing capability, with linkages to Monash University and CSIRO business units. CSIRO business units located in the area include:

- Atmospheric Research
- Manufacturing Science and Technology
- Mathematical and Information Sciences
- Minerals
- Molecular Science (also at Parkville)
- Petroleum Resources
- Plant Industry
- Telecommunications and Industrial Physics
- Textile and Fibre Technology.

There are also a large number of technology-based companies located in the Clayton/Mulgrave area.

6.2.3 Alfred Medical Research and Education Precinct.

The Alfred Hospital, in Prahran is also a centre for research and development. It is the site for the Baker Institute.

6.2.4 Werribee

The Werribee area is the location for a number of organizations involved in plant and animal production and food processing. It is the location of the Dairy Process Engineering Centre and Food Science Australia. It is also the location of a campus of

the Victoria University that undertakes teaching and research in food science and technology.

There is a proposal to develop some land at Werribee for a Biotechnology Institute – as a joint venture between Victoria University and the Austin Research Institute.

6.2.5 Fishermans Bend

Fisherman's bend is the location of the former ASTA facility and now owned by Boeing. It is also the location of the DSTO Aeronautical Laboratories. The RMIT has a Centre located adjacent to the Boeing establishment.

We understand that there is a high level of collaboration with students, as well as participation in the CRC for Advanced composite structures

6.2.6 Horsham

Horsham is the location for a number of Agriculture Victoria Institutes. Ag Victoria has suggested establishing Horsham as another 'technical precinct' (grains, pulses) with greater involvement from commercial partners. The Department considers that State Government support could involve the provision of space to attract multi national corporations that might already be trawling Australia for a potential local site

6.2.7 Latrobe Technology Park[24]

La Trobe R&D Park is situated on a 20 hectare site overlooking the Bundoora campus of La Trobe University. It is an unincorporated commercial entity, fully owned and managed by La Trobe University.

La Trobe R&D Park is a three-stage facility for technology based businesses, providing options in services and accommodation to suit the needs of start-up, graduate/mature and large businesses.

6.2.8 The RMIT Technology Estate[25]

Royal Melbourne Institute of Technology (RMIT University) proposes to create a unique environment in which the university, the local community and participants in the RMIT Technology Estate form an inter-related and interacting community that generates substantial long term economic and life-style benefits for the region as a whole.

The RMIT Technology Estate will integrate high technology industry, residential areas, commercial, retail, services, hotel and motel accommodation, and recreation facilities. Industry participants will be users and developers of leading edge technologies who recognise and value the synergies and benefits that emerge through close interaction with similar industries and proximity to a university focused on R&D, education and training, and applications of emerging technology.

[24] Information from La Trobe University Website
[25] Information from RMIT Website

6.2.9 Ballarat Technology Park[26]

The Ballarat Technology Park has been developed in conjunction with the City of Ballarat to provide a centre for the region's information technology industry. Situated on a 29 hectare site within the campus of the University of Ballarat, the Park comprises 12 sites that specifically cater to the needs of information technology. Nearing completion is the most advanced optical fibre network in regional Australia. Cable will soon to be available throughout the Central Business District.

It is intended that the Park will play a strategic role in the growth and development of new ventures that in turn stimulate broader economic development and job creation. Close proximity to the University of Ballarat provides ready access to highly skilled and experienced research scientists, technical staff and IT graduates.

6.3 Shortcomings in the cluster approach

The definition of a "cluster" raises some important issues in this Audit and Review. While it is possible to identify similar types of institutions and firms located in specific postcode areas, or precincts, in Melbourne, this does not imply economic integration or substantial collaboration. In this respect, it is important to distinguish between clusters and "co-location".[27] *Co-location does not equate with collaboration.*

The economic benefits associated with clustering flow from an integration of technology development activity with commercialisation of research outcomes. Invariably, this involves the presence and commitment of a large company with its own research commitment together with product development and marketing (including market access) capability. With Australia's small population base, g*lobal market access is a critical success factor for Australian STI effort*

The geographic positioning of a large organization, that has many suppliers and a broad base of clients and customers, as well as access to common infrastructure will generally flow through to decisions of smaller organizations to locate within close proximity. Close physical proximity reduces transaction costs and increases returns. It may increase local employment – but not necessarily impact on innovation.[28] Town planning schemes and zoning regulations may also influence co-location decisions.

Major manufacturing establishments, public hospitals and universities have always had significant "pull power" throughout Australia. The development of non-market forms of collaboration may develop within these co-location arrangements – but equally, firms may choose to collaborate with organizations that are geographically distant. Research undertaken in relation to strategic alliances and business networks suggests that organizations collaborate across substantial distances.

We would argue that co-location is driven more by competition than collaboration. Firms may be attracted to one location because it is important for competition - in that they want access to a specific client base and skilled staff and resources. The notion of collaboration or cooperation in critical business areas is not on the agenda. *Similarly, the location of research institutes in close proximity in Melbourne does not of itself imply*

[26] Information from Ballarat University Website
[27] Co-location is often impacted by statutory land use planning, availability of land and property development considerations.
[28] Large manufacturing assembly plants are a good example. They create many jobs and opportunities for component suppliers

close collaboration in research effort. Research Institutes may be fiercely competitive in their quest for funding from limited resources.

We were advised during the Review of competition between research institutions within Melbourne – which could gain a great deal of benefit by collaborating on a regional/metropolitan wide basis. A number of University Departments have already begun to collaborate in their research efforts. *Considerations relating to multiple interactions and relationships, social interaction and local culture would mean that clusters are more than precincts.*

6.4 Collaboration and community

Recent thinking about interactions has given attention to the scope for cooperation and collaboration through partnerships and alliances as well as developing *a sense of community*. These arrangements may not necessarily be concentrated in a single geographic area. *What is important is an organization's capacity to form alliances and partnerships on a regional, national and international basis to enhance capability.*

With rapid advances in information transfer and global distribution systems, the concept of cluster is being overtaken by reference to "communities bounded and bonded by values"[29]. Values create an ability to share ideas easily across great distances. Communities of values have clear, strong and distinct identities that have meaning to members and distinctiveness to non-members.[30] They enhance the capacity to develop *social capital* - a factor that is becoming recognised as a key driver of economic growth.

Peter Senge, author of the widely acclaimed book, *The Fifth Discipline*, has commented recently that:

> The discipline of innovation is practised successfully in many domains of human affairs, notably the arts and science. Interestingly, when it is practiced effectively it is invariably done within communities, among diverse individuals who share a common purpose. Energised communities, for example, characterise most periods of innovation in the arts, such as the birth of impressionism, or modern dance, or jazz. Likewise, science at its best is an intensively collaborative undertaking; even when the collaborators are strong individuals competing with one another, their competition occurs with a larger mediating community. Likewise in business, real innovation is much more collaborative than at first appears.[31]

A number of Melbourne based research institutes collaborate extensively on a regional, national and international basis. A number also receive funding from international sources including the National Science Foundation. There are, however, values in the STI infrastructure that have a distinctive "Melbourne" orientation. To the extent that it is important to retain the use of the term "cluster", but at the same time emphasise sharing, cooperation, collaboration and community values, then i*t is probably sensible to regard Melbourne as the basic cluster unit for most purposes*.

Recommendation

> **The term "cluster" for the purpose of STI investment and analysis be identified as encompassing the "whole of Melbourne". The term**

[29] Ulrich, Dave, "Six Values for Creating Communities of Value, Not Proximity", in Fraces Hesselbein, et.al. (ed), *The Community of the Future,*, p.157.
[30] Ibid, p. 159
[31] Senge, Peter, "The Practice of Innovation", in Frances Hesselbein and Paul M Cohen, eds, *Leader to Leader*, New York: Jossey Bass, 1998, p.67.

cluster be taken to encompass cooperation, collaboration and building "a community of values".

7 Facilitatory Interaction

7.1 University-Industry Interface Organizations

University interface organizations are not as prevalent as they are in the UK and Europe. There are two significant examples:

The Australian Mineral Industries Research Association Limited (AMIRA) undertakes development and management of jointly sponsored research and development in mining, coal, oil and gas industries, including technology transfer services for the benefit or member companies. It administers Australian Coal Association Research Program for Australian Coal Research Ltd

All research and development work is contracted, principally to universities, the CSIRO and CRCs. AMIRA is a participant in five CRCs

7.2 Industry And Business Associations

Business associations play an important role in promoting policies supportive of innovation. With the recognition that innovation must come from business, industry associations are directing attention to promoting and encouraging innovation among their members

The Victorian Employers Chamber of Commerce and Industry (VECCI) and the Australian Industry Group (AIG) have a strong presence in Victoria. They have tended to have a strong industrial relations focus, but that role is now changing as they become more involved in matters concerned with industry policy, and particularly innovation.

Their capacity to contribute to the STI resource base is constrained to some extent by an unwillingness of member bodies to commit resources for collective and collaborative effort.

7.3 Professional Associations

There are also professional associations that provide for strong university-industry interaction, such as the Institution of Engineers, Medical Colleges, etc

Professional associations assist and facilitate the sharing of information and knowledge in a science and innovation "community". In the "knowledge economy" professional associations are becoming increasingly important as a mechanism for professionals the keep up to date with developments in knowledge and technique.

Many professional associations require their members to allocate and commit to formal education processes to retain registration.

8 Companies With A Significant Commitment To The STI Base In Victoria

A full listing of companies contacted for possible inclusion in the STI Database base is located at Annex 3. Detailed below is information about R&D performing companies and some comments about venture backed companies.

8.1 R&D Performing Companies

The companies that contribute in a significant way to Victoria's STI base is indicated by their expenditure on research and development. Information obtained for the 1997 R&D Scoreboard indicates that 41 of the top 100 R&D performers have their head offices in Victoria. Information about the level of R&D investment is provided in Table 3. Information concerning whether the company provided information for inclusion in the STI database, whether they are participants in a CRC and whether they have involvement with a University based research centre, is also provided:

Table 3: Victorian Companies - Major R&D Performers

Company Name	R&D Expenditure 1996-97 $'000	Sector	Information provided for the STI Database	Participation in a CRC	Contact with a Research Centre
Telstra	239.0	Telecommunications		X	X
Broken Hill Proprietary Company Limited	200.0	Mining		X	X
General Motors Holden	139.0	Motor Vehicle & Part Manufacturing			X
Ericsson Australia Pty Ltd	109.5	Telecommunications		X	X
Ford Motor Company of Australia Limited	106.0	Motor Vehicle & Part Manufacturing		X	X
Rio Tinto (RTZ-CRA Group)	94.6	Mining	X	X	X
ICI Australia Limited	39.2	Petroleum, Coal, Chemical & Associated Products			X
CSL Limited	28.2	Biotechnology	X	X	X
Newcrest Mining Limited	25.6	Mining			
Australian Postal Corporation	25.0	Postal & Courier Services			
Hewlett-Packard Australia Limited	21.5	Computer Software & Services		X	X
Glaxo Wellcome Australia Ltd	18.3	Pharmaceuticals	X	X	X
NEC Australia Pty Ltd	13.7	Telecommunications			
AMRAD Corporation Limited	13.4	Scientific & Medical Research	X	X	X
Transfield Defence Systems Pty Ltd	13.0	Machinery & Equipment Manufacturing			
Pasminco Limited	11.7	Mining		X	X
Nortel Australia Pty Limited	11.7	Telecommunications	X		X
Great Central Mines Limited	11.3	Mining			
Varian Australia Pty Ltd	11.3	Medical & Scientific Equipment Manufacturing			X
Pacific BBA Limited	9.3	Motor Vehicle & Part Manufacturing			
Merck Sharp & Dohme (Australia) Pty Limited	8.4	Pharmaceuticals		X	
National Consolidated Limited	7.6	Motor Vehicle & Part Manufacturing			
Ceramic Fuel Cells Limited	7.3	Scientific & Medical Research	X		
Acacia Resources Ltd	5.8	Mining			
Dow Chemical (Aust) Ltd	4.5	Petroleum, Coal, Chemical & Associated Products			

Company Name	R&D Expenditure 1996-97 $'000	Sector	Information provided for the STI Database	Participation in a CRC	Contact with a Research Centre
Tickford Vehicle EngineeringPty Ltd	3.0	Motor Vehicle & Part Manufacturing			
Biota Holdings Limited	2.9	Pharmaceuticals	X		
Olympic Amusements Pty Ltd	2.9	Machinery & Equipment Manufacturing			
ZC Mines Pty Limited	2.7	Mining			
Technology Concepts Pty Ltd	2.1	Rubber & Plastic Product Manufacturing			
North Forest Products	2.0	Agriculture			
Hella Australia Pty Ltd	1.9	Motor Vehicle & Part Manufacturing			
Aberfoyle Resources Limited	1.8	Mining Services & Exploration			
Multistack International Ltd	1.4	Machinery & Equipment Manufacturing			
Ticor Limited	1.3	Mining			
Bostik (Aust) Pty Ltd	1.3	Rubber & Plastic Product Manufacturing			
Rofin Australia Pty Ltd	1.3	Medical & Scientific Equipment Manufacturing			
Clemenger BBDO Limited	1.3	Property & Business Services			
Ego Pharmaceuticals Pty Ltd	1.2	Pharmaceuticals			
Open Software Associates Limited	1.1	Computer Software & Services			

The data point to a very strong commitment to manufacturing R&D. Further information about R&D investment activity is provided in Part 3.

What is of particular interest from the data in Table 3 is the very low participation rate of top R&D performers in the CRC network and in the University Research Centre network. Participation is much higher for research performers that spend more than $10m on Research and Development.

8.2 Venture Backed Companies

The emergence of a strong venture capital sector in Australia, and in Victoria[32], has provided opportunities for individual effort and enterprise to be transferred to and incorporated in an organisational context.

One of the most important functions of a venture capital investor, particularly at the early stage of the business life cycle, is to strengthen the management infrastructure and support the marketing effort with a view to exiting the investment through sale to another organization or through public listing.

Venture capital investors do not generally invest in basic research and development.[33] However, venture capitalists have a major role in taking proven technologies through to market.

[32] There are 27 Venture Capital Firms with head offices in Victoria. A number of others located inter-state have made investments in Victorian companies.
[33] In the Information Technology area, over 90 percent of venture capital funds are used for marketing.

9 Access To Finance For The Commercialisation Of STI Opportunities

This section of the report addresses issues raised in the terms of reference concerned with access to funding for STI purposes, including finance for commercial application.

9.1 Background

Until recently, it has been difficult for small innovative companies to access finance for growth. Entrepreneurs, including scientists and academic entrepreneurs, faced rejection from banks and other lending institutions, while venture capitalists and other private equity investors were small in number and lacked the resources to commit to early stage investments.

The situation changed dramatically over the last two years. By the end of the 1990s the venture capital sector in Australia was well cashed-up. Australian institutional investors began allocating a larger proportion of their funds to private equity, while off-shore investors were actively looking for investment opportunities.

Small innovative companies began to have success in attracting finance. A plethora of venture capital managers and other private investors emerged to take advantage of the potential returns to be gained.

Many factors played a part in changing the climate for small innovative companies. By far, the biggest single factor that assisted new companies in their efforts to attract equity funding was the roaring success of the world stock exchanges and particularly the NASDAQ. As the 1990s progressed there was a situation where it was true to say that money was not the problem.

Of course, there were still entrepreneurs who would argue that they could not attract funding. However, in most cases, the problem was not with a lack of available finance, but rather with the proposition that was being put forward. For example, there may have been problems with the actual product or service and its potential market, or as is more often the case, the management team involved could not convince an equity provider that they had the ability to see the venture through to a stage where the investor could exit at the required rate of return.

It is often said that academics are more concerned with tenure and money to undertake research rather than being involved in commercialisation of technologies they have created. While this may be true in some instances, it is also the case that some scientists see their future in business rather than academia. What is often required is education and training in business imperatives and instilling an entrepreneurial culture.

9.2 Recent developments in Victoria

Until recently, most of Australia's venture capitalists were based in Sydney. The few exceptions included Rothschild Australia, Advent Management Group, Greenchip Funds Management, Nomura/JAFCO Investment (Asia) Ltd, and National Australia Investment Capital. There were also a number private investors and organizations such as VECCI and Business Angels Pty Ltd. The large institutional fund of funds, Development Australia Fund (DAF), is also located in Melbourne and has been a pioneer in private equity investment in Australia.

9.3 Venture capital firms based in Victoria

There are currently 27 formal venture capital funds operating in Victoria. These are listed below. Further information is provided in Report Attachment 4. Table 4 below provides an indication of the access of companies seeking equity finance to seed and start up capital.

Table 4: Venture capital Firms Based in Victoria

VC Firm	Investment Focus			
	Seed	Start Up	Early Expansion	Late Stages
Acrux Ltd	√	√	√	
Advent Management Group Ltd				√
Australian Development Fund Ltd	√	√		
BCR Asset Management Pty Ltd				√
Citadel Pooled Development Ltd				√
Concept Investments Pty Ltd		√	√	√
Development Australia Fund: Fund of Funds Manager			√	√
ES Group Ventures	√	√	√	√
Flinders Capital Ltd				√
GE Capital Equity Capital Group				√
Greenchip Funds Management Pty Ltd			√	√
Hochma Development Fund Pty Ltd				√
Lion Selection Group Ltd	√	√	√	√
Mawson Management Pty Ltd	√	√	√	√
Momentum Funds Management Pty Ltd	√	√	√	
National Australia Investment Capital Ltd				√
Nepean Capital Partners Pty Ltd				√
Nextec Development Capital Ltd		√	√	√
Nomura/JAFCO Investment (Asia) Ltd				√
Pacific & Orient Investment Trust	√	√	√	√
Rothschild Bioscience Managers Ltd	√	√	√	
Rothschild eCommerce	√	√	√	√
Senetas Corporation Ltd	√	√	√	√
Smallco Development Capital Pty Ltd			√	√
Starpharma Pooled Development Ltd	√	√	√	
Victorian Venture Capital Managers			√	√
Wine Investment Fund.			√	√

Source: Derived from *Australian Venture Capital Guide, 2000*

Of the 27 firms, only 11 are interested in very early stage (seed) finance. Most of these funds have a very small capital base and the amounts available are small – particularly for further equity injection. Many of the seed funds are Pooled Development Funds

Recently, a number of new venture capital groups have opened offices in Melbourne. They include many brand new venture capital managers and groups of high net worth individuals (business angels) as well as state branches of large institutions, as well as Victorian branches of Sydney based venture capitalists, such as Allen & Buckeridge (A&B). A&B are expected to commence operations in Melbourne in May 2000 and have already invested in the following Victorian companies:

- eChoice
- SouthRock Software
- Authentic8

- wishlish,com.au
- eKit.com

Even when venture capitalists are primarily located in one centre, they will invest widely. Equity Partners, a Sydney based venture capital manager, reported that a significant number of its recent deals were located in Victoria.

Further information regarding their operations and investment preferences is located in Attachment 5.

9.4 Business introduction services

Victorian entrepreneurs have access to a number of business introduction services. They include:

- Australian Stock Exchange Enterprise Market
- Business Angels Pty Ltd
- Bendigo Stock Exchange
- VECCI's Business Angels Service.

Further information about these programs is provided in Attachment 6.

9.5 Product development funding

Victorian entrepreneurs and innovative companies also have access to a wide range of government programs to assist in the commercialisation of innovation. They include:

- Australian Greenhouse Office
- Cinemedia Digital Media Fund
- Industry Research and Development (IR&D) Board
- The Commercialising Emerging Technologies (COMET) program

Further information about these forms of assistance is provided in Attachment 7.

9.6 The role of intermediaries

Intermediaries such as accountants, lawyers, corporate advisers and consultants are playing a far more active role in assisting entrepreneurs attract growth finance. The role played by many intermediaries is sometimes the crucial link between success and failure in finding an equity investor.

There will always be entrepreneurs seeking equity finance. The barriers facing many entrepreneurs are varied and range from lack of business know-how through to issues surrounding control. This is where intermediaries can and do play a very important role.

The last two years has also seen the emergence of science and technology commercialisation "brokers". These organizations provide a bridge between the investor and the researcher by addressing business and investment issues. They may also work with the researchers to commercialise their research. Organizations involved in this include:

- Technology Structuring Limited
- County Investments

With the change in IP policy at the University of Melbourne there are opportunities for a market to strengthen in this area as researchers have the opportunity of using faculty based business advisers or going to the market.

People with skills in technology commercialisation and business management capability are in high demand, not just in Australia.

Feedback received from some equity providers raised concerns about the entry of some intermediaries who themselves do not fully understand what a venture capitalist or equity provider is looking for in an investment. Some venture capitalists reported that they would have preferred to work with the entrepreneur from the beginning of the 'idea' as in some cases the external assistance had hampered the process.

Despite the increase in intermediaries, there is still a need for education of both entrepreneurs and advisers. The reason that most venture capital managers reject a proposal is due to the failure of the business proposition and its management team to be investment ready. Many intermediaries are, in fact, acting for an organization that will be involved in the commercialisation process – on the basis that they will be party to a fee r commission for the "introduction".

The investment climate is changing so rapidly that it is now possible to find an equity investor who will actually assist with the development of the business plan, if they are convinced that the 'idea' has potential. However, the owner of the idea, particularly in the science community, may not be fully aware of the full commercial potential of that idea in full commercial application. While there have to be rewards for entrepreneurial risk, it is also important that people are not taken advantage of.

Venture capitalists are always looking for a deal that is going to provide high returns on the investment. This type of deal also equates with a business proposition that is unique, has a large, clearly defined market that is hard for competitors to enter, and has an entrepreneur and management team that are capable and committed to achieving the goals set out in the business plan. More often, the business plan will include potential strategic partners that the company can link with to reach market share.

Recommendation

> **The State Government encourage the development of a network of "independent brokers" within the science community who can provide objective advice to research teams working in an academic environment in negotiations with equity providers.**

9.7 Corporate venturing

A brand new venture capital fund that is based in Melbourne and operates on the concept of a corporate venture capital program is the Rothschild e-Fund.

E-Fund's investors are all large corporates in the convergent business sectors of telecommunications, electronics, multimedia, the Internet and automotive industry. The investors are all mutually compatible and can assist the venture fund with due diligence activities. They can also provide opportunities concerning strategic partners.

Corporate venturing is a popular activity in the US, as corporations realise they need to keep innovating to maintain market share. While the big corporations are not able to

satisfy their own innovation requirements internally, they allocate funds to a number of different venture capital managers and incubators that are skilled at fostering innovation.

In this way, 'older world' economies and large corporates can build linkages with small, innovative companies that can feed the required research and development needed to maintain a leading edge in an increasingly global economy.

9.8 State Government

The Victorian Government does not have a fund that can be used to invest in emerging and start up businesses.

Notwithstanding the availability of funding through venture capital funds, very little funding finds its way to the very early stage, particularly where IP is not secure. It is particularly difficult to attract funds to the medical research sector, for example, where proof of concept can take many years and is then subject to external regulations, risks of patent infringement and ultimately, market acceptance.

In the United sates a number of State Governments have supported the establishment of investment funds, particularly in the biotechnology area. The North Carolina Bioscience investment fund, for example, was established with $7.5m in public funds placed under the control of the North Carolina Biotechnology Centre and managed by a private investment firm. A further $8.5m has been raised from investment funds.

The State Government may wish to support the provision of seed capital through cluster based [see below] organizations and commercial funds to assist in the formation of spin-out companies at an early stage in biotechnology and other areas. This assistance may involve getting the IP to a stage where it is commercially valuable and attractive to downstream investors.

Recommendation

> **The Victorian Government consider providing funding for seed and "pre-seed" developments in biotechnology and other research intensive sectors through an independent sector focused organization in collaboration with established investment funds**

The need for investment support in information, communication and communications is not readily apparent as new venture capital firms actively seek deals that they can quickly get to market.

9.9 Support for regional enterprises

Regional Victoria has seen the recent establishment of the Bendigo Stock Exchange and the commitment of local people to facilitate investment in regional enterprises. Most venture capitalists maintain that "it does not matter where a business comes from, but rather where the business is heading." Some feedback tended to indicate that many regional businesses, apart from being inadequately prepared for an equity investor, also needed to take their proposition to the investment community and be prepared to "keep knocking on doors" until successful.

10 Biotechnology in Victoria

The Terms of reference sought specific comments about infrastructure for the biotechnology sector.

10.1 Background

The biotechnology sector is undergoing significant change and development. While Australia and Victoria has largely missed out on the biotechnology "boom" that has occurred in North America and Europe, there are still major opportunities. At this stage, Australia, and Melbourne, are strong on the Science and Technology aspects of the STI resource base; there is a weakness with respect to the "I" component. In particular:

- The venture capital sector does not have a strong capability in biotechnology – there is only one firm in Melbourne that specialises in biotechnology investments
- Because of the absence of seed and early stage venture capital for start-up companies, the opportunities for development of the biotechnology sector are severely constrained: the culture of VC firms in Australia is that they are not "patient" enough for biotechnology
- In contrast to the UK, Ireland and Germany, and parts of the US, which have strong biotechnology sectors, Australian Governments do not invest in biotechnology companies at the start-up stage
- There is not, therefore, a large pool of biotechnology companies that can enter into collaborative R&D arrangements with pharmaceutical companies for drug development
- The absence of seed capital for start up companies means that technology passes directly from research laboratories to the pharmaceutical companies without the opportunity for further development of the technology and for the generation of employment.

There is now an appreciation on the part of pharmaceutical companies that they must incorporate biotechnology into their drug discovery and development strategies in order to survive[34]. Biotechnology aided drug discovery differs from the traditional "pipeline" strategies which are very time consuming, risky and expensive. Biotechnology provides for a mix of combinatorial chemistry for rapid syntheses of drugs, and genomics for finding specific targets, can shorten the discovery process significantly.

Biotechnology based drugs are seen as the direction of the future. It provides pharmaceutical researchers the opportunity to tailor new compounds with above average chances of making it through testing and getting compounds out of the laboratory quickly[35]. The difficulty that the pharmaceutical companies have is acquiring biotechnology capability. They have two options:

- Develop the capability in-house, either by establishing their own labs or acquiring them through mergers and acquisitions
- Enter into licensing agreements or seeking R&D collaborations.

In-house and outsourcing options have strengths and weaknesses. A critical issue is corporate culture – and in particular, the degree of comfort with outside research groups.

[34] McKay, Niall, "The New Crusades", *Red Herring*, April 2000, p298
[35] "Research Fellows", *Red Herring"*, p. 306

- Internal approaches allow companies to focus on particular diseases and to develop new tools to accelerate drug discovery and development as well as retaining control over IP. But they can be bureaucratic and their orientation to disease means that they might miss out on off shoots to research that might lead to therapies for medical conditions outside their spheres of interest.
- In principle, collaborations and joint ventures provide access to a close knit entrepreneurial environment of small biotech companies. They can also partner with academic researchers who have excellent ideas and achievements, but because of an unwillingness to lock into a particular patron, prefer to license the results of their research.

Either way, the acquisition of the technologies is still expensive – either in the form of new in-house facilities or in licensing. Cost issues are actually forcing mergers of the large pharmaceutical companies. There are major implications in the newly merged arrangements as parties have different approaches and networks of biotechnology contacts. They include:

- There will be fewer contracts with biotechnology companies and research laboratories
- The larger companies will also want to exercise more control over the IP by pulling projects in-house at an earlier stage.
- Companies will tend to retrieve projects once they show signs of leading to products for the drug pipeline.

Nonetheless, no one company will have all the expertise required to produce the innovative solutions for the numerous unmet medical needs still present. Many companies seek new research capabilities and high potential drug candidates from external sources. Drug companies are now tending to build portfolios of biotech investments.

10.2 Implications for Victoria

The strength of the science base in biotechnology in Victoria is widely acclaimed. One of the problems that Victoria must overcome is the distance from large markets. As we have indicated earlier, it is most unlikely that scientific discovery will result in commercialization without the contribution of equity finance and the involvement of a large company.[36]

There is also a related issue that a great deal is being done by government agencies to understand how the biotechnology sector works, and to "develop policy", but very little is actually being delivered. In its response to the Audit and Review, the Walter and Eliza Hall Institute commented that:

> There is a lack of co-ordination, and consequent duplication of data-gathering about biotechnology. At the federal level there are: Biotechnology Australia, IP Australia, Emerging Industries Groups [Industry, Science and Resources]: similar multiple groups, roundtables and forums/conference organizations is occurring at State level also. It is becoming impossible to know of real funding sources - eg. COMET, BITS, R&D START, so that we can actually begin to achieve the goals of a vibrant biotechnology industry.

[36] There is, incidentally, now a growing literature on the importance of large organizations in innovation. The research of Alfred Chandler jnr has been of particular significance. See Chandler, Alfred D. et al.(eds) Big Business and the Wealth of Nations, Cambridge: Cambridge University Press1997

> The Australian Governments (State and Federal) must appreciate the urgency and begin to implement its strategies, and establish funding mechanisms. We are rapidly slipping behind our international competitors.

We would argue that development of an industry using biotechnology capability should focus clearly on the *innovation* aspect[37] – that is bringing the technologies into a commercial application (this can include "public benefit" applications). This means being able to access the large European and US markets where demand is located, but which are also highly competitive.

With the developments in the pharmaceutical industry, Victoria would benefit from:

- Support from a publicly sponsored equity fund for seed and early stage commercialization of biotechnology with a view to securing IP and developing and implementing an integrated marketing and communications strategy[38]
- A clear understanding that funding is for product and management development and not further "discovery" research
- Encouraging, through FDI initiatives, pharmaceutical companies to locate (or remain) in Melbourne
- Advocating greater cooperation and collaboration among research centers and institutes, through consortiums and partnerships, that can work effectively in joint ventures with pharmaceutical companies
- Making available advice and assistance to scientists and "academic entrepreneurs" in their negotiations with large pharmaceutical companies.

There are a number of biotechnology companies that are doing well and have developed effective working relationships with the pharmaceutical companies. These include Institute of Drug Technologies and AMRAD. However, for the Victorian biotechnology base to move from "S&T" to "I", investments must be made to support the commercialization process.

It is of interest to note that in our discussions, a number of scientists active in the commercial aspects of medical research did not advocate investment in new buildings. They argued that finance for buildings was straightforward in a commercial environment (banks and finance companies like investing in real estate) and that collocation was not an issue[39]: the main issues related to cooperation and collaboration and access to markets.

The issues that have been addressed in this Section have been the subject of recommendation in other parts of the report.

10.3 Biotechnology in Food and Agriculture

The potential for application of biotechnology in agriculture is well recognized. It allows for greater crop yields that use less land and less toxic chemicals. With the rapid depletion of Australia's natural capital associated with the problem of dryland salinity there are major long terms issues and strategies that can be developed around agricultural biotechnology.

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[37] We assume funding for research would continue through existing mechanisms, but as discussed elsewhere in this Report, with a more focused "consortium" approach.

[38] The current Commonwealth Innovation Investment Fund (IIF) Program does not sufficiently address needs in the biotechnology sector.

[39] AMRAD is located in Richmond and IDT is at Boronia.

There are, however, some issues to be overcome, the most fundamental of which relates to food safety. Much is still unknown about the long term effects of GM crops on the environment.

It has been pointed out that the companies that pioneered bio-engineered crops made a major miscalculation in that they failed to recognize an "inherent gap in their channel to market and the market itself"[40]. As technology companies, they saw their customers as the farmers who purchased seed – not the consumers of food. Thus:

> Instead of initially engineering seeds with tangible benefits to the public, like vitamin-enriched foods, they chose to develop seeds that appealed to farmers. In the case of Monsanto, its first product was a soybean seed called Roundup Ready, which could withstand Monsanto's own special herbicide Roundup. Although the company claimed that the technology would lead to less overall herbicide use, to some consumers it had the appearance of commercial craftiness.[41]

The reaction to the consumer backlash has seen many of the large biotechnology companies spin off their biotech agriculture operations. Monsanto is in the process of being acquired by a pharmaceutical company with the acquirers intending to stick to biotech drugs.

Consumer demand for non-GM crops creates opportunities for innovative approaches to improving agricultural productivity using the resources of the Victorian Agricultural Institutes, the CRCs and the University Research Centres. Food manufacturers are now competing on the basis of the lack of bio-engineered ingredients. There are several issues to be addressed, including:

- Developing a market for non-GM foods
- Creating an awareness that vitamin enriched foods are safe
- Developing technologies that will restore and replenish natural capital.

These issues should be addressed in the context of further development of the Victorian STI strategy.

[40] Cukier, Kenneth Neil, "Seeds of Doubt", *Red Herring*, April 2000, pp318-9
[41] Ibid, p. 319

11 Summary Of Comments From Respondents About The STI Resource Base

The request for information sent to research organizations and science and technology based companies included a question about gaps and shortfalls in Victoria's STI base. The responses to the question are summarised in this Section.

11.1 General comments

From an overall perspective, respondents identified a number of specific gaps. These are summarised below.

Gaps by Respondents Identified in the STI Base

Identified Gap	Number of responses	Percent
Knowledge	21	30.4
Leadership	29	42.0
Networks	10	14.5
Relationships	10	14.5
Technology	12	17.4
Education and Training	22	31.9
Assets		
Facilities	32	46.4
Machinery./equipment	27	39.1
Libraries	1	1.5
Collections	0	0.0
Products	3	4.4
Databases	3	4.4
Intellectual Property	4	5.8
Funding	39	55.1
Locations	3	4.4

Generally speaking, respondents showed neither extreme satisfaction nor dissatisfaction with existing policy programs aimed at improving the state of Victoria's science, technology, and innovation infrastructure. Responses were generally premised on the belief that while current government policies may be limited in many respects; they are *not* in need of drastic overhaul. Having said this, nearly every respondent made critical comments on the established policy framework, or suggestions for reform. A summary of the major points follows:

11.2 Funding

Almost all respondents made complaints about inadequate levels of funding for research facilities and equipment. Several respondents were somewhat 'cynical' about government commitment to supporting research and innovation (both State and Federal) – they believe that policy development in this area tends to be fickle and fad-driven.

Some of the more sophisticated responses commented that the established facilities and equipment in Victoria may be aging and increased funding was probably a necessity to

keep local research and innovation efforts relevant and in-line with international best practice. One example given was in the area of biological science and plant cell research.

Many of the respondents commented on the skewed focus of research funding in several areas, and the presence of a number of key strategic gaps. Respondents remarked that ongoing research efforts appear increasingly slanted toward conservative areas, and away from controversial and/or high-risk endeavours (particularly apparent in environmental and agriculture research).

11.3 Research effort

There was some concern that the apparent bias towards conservative research effort and outcomes might be responsible for incapacity across an entire industrial sector. This was seen as a key problem in biotechnology research and development, as well as pharmacology. One respondent with a speciality in research on fluid dynamics pointed to the irony that while Victoria is a major centre in Australia for automotive and manufacturing industries, support for this key area of applied mathematics is especially poor.

11.4 Institutional fragmentation

Several respondents remarked on the tendency for governments at both the State and Federal level to create new organizations and mechanisms to facilitate technological research and innovation when proven organizations were already in place. Some of this policy behaviour was explained as a structural effect of government in this country (i.e. Australian federalism) and poor institutional performance, but oftentimes the high quality of existing facilities seemed impossible to ignore.

One example given in the field of mining and energy was the Australian Mineral Industries and Research Association (AMIRA). Linked to the concern about institutional fragmentation, many respondents complained of a lack of continuity in research and development programs sponsored by the government. This problem seems to be especially an issue in the area of agricultural research, although some respondents in manufacturing also raised concerns.

11.5 Public private linkages

There were a series of comments from a cross-section of organizations about links between public and private R&D efforts, and between various stages in the R&D lifecycle. One public sector respondent specializing in food research commented that while facilities did exist to allow for cooperative projects, there was little substantive effort to encourage private sector participation. A university respondent working in the area of aerodynamics and hydrodynamics expressed amazement that the defence industry had not been made aware of their work.

11.6 Support for commercialization

Another respondent in medical science commented that links between discovery research and commercialisation were especially weak in their area of expertise. Broaching the overall topic of linkages, a respondent from the manufacturing industry pointed to a lack of simultaneous briefing sessions for industry and academic

representatives on state of the art techniques, and called for more 'one-stop-shop' facilities to encourage public-private interaction.

11.7 Scale of capability

A number of larger respondent organizations commented that they were simply too big to make use of the established facilities and mechanisms offered by the government to encourage R&D and innovation. Where gaps in local techniques and knowledge created demand for research and innovation services, they simply looked abroad and within their companies for support. On the other hand, several of these larger respondents also complained about the limitations on this kind of 'internal outsourcing.' One company in the computer industry commented that links with head-office in the US were less than perfect, and a rationale may exist for conducting more R&D work in Victoria.

11.8 Cooperation and collaboration

A Project Director in a leading Medical Research Institute commented that Victoria's medical research effort is spread through a significant number of research institutes located throughout the metropolitan area. Under such circumstances collaborative effort is not easily facilitated and researchers may tend to work in greater isolation than need be the case.

Several respondents had concerns that their research and innovation efforts might well be lagging behind best practice in terms of their use of information technology, but were unable to make an informed judgement on the matter (an issue especially for those working in the agricultural sector).

In an associated comment, a respondent from the information industry suggested that there was a chronic need for a directory of available science, technology and innovation resources in Victoria and the rest of the country. The respondent continued that this directory might include a list of funding schemes and organizations that support STI endeavours.

12 Investments And Actions To Sustain And Develop Victoria's STI Resource Base

This Section draws on the framework outlined in the previous Section and the information contained from the Request for Information, our analysis of material provided, discussion and consultation during the Review, and an understanding of organisational characteristics and attributes in the STI resource base. Specific information about STI current capabilities is provided in Part 3 and requirements identified by respondents is provided in Part 4

There are numerous proposals for STI investment - in facilities and equipment, capability building, people, and supporting cooperation and collaboration. We are not in a position to assess the merit of these proposals, but suggest that they be fully appraised in terms of their contribution to overall STI capability and where economic benefits are likely to be sustained.

Assessment should involve examining current strengths in existing capability and directing investment to areas where Victoria is doing well from an *overall* STI perspective. This means providing support for areas that are not only strong in theoretical conception and technical invention, but also looking at actual and potential opportunities for commercial exploitation.

As we have indicated earlier in the Report, successful and sustained commercial exploitation is the critical aspect of innovation. The material provided in Part 3 and in the *Compendium of STI Organizations in Victoria* is intended to assist in this assessment process.

12.1 Facilities and equipment

There were a number of proposals from respondents proposing investment in equipment to enhance Victoria's science, technology and innovation base. Most decisions to invest in scientific equipment for research and development will be made by organizations on the basis of established investment appraisal criteria.

A total of 29 respondents identified specific gaps in available facilities and proposed investment action. These proposals are set out in detail in Part 4.

A number of researchers commented that buildings were not as important as investment in specific research programs and acquisition of technical knowledge. There was a view that buildings could be financed from a variety of commercial mechanisms – but specialised equipment was where public support was required.

The interest and involvement of government in public investment occurs in situations where:

- There is substantial public benefit – for example to achieve public health outcomes
- The Government takes a role in facilitating collective investment by a number of organizations or between organizations and the research sector
- There is an opportunity to "scale up" a facility to provide broader access than would be the case if a company or research organization invested solely on its own behalf.

Of critical importance in assessing proposals for additional facilities and equipment is an understanding that funds are being sought for *an investment* as opposed to a *grant in aid* to reward community or business effort. This has been the traditional approach to allocation of government support.

A decision to invest, whether in a privately or publicly sponsored proposal, must be based on a sound business case. A business case is the foundation for moving forward. It reflects a view that something is worth doing from a "business" viewpoint. That is*:*

- It focuses on the benefits of a proposal
- It should draw attention to the reasons why an investment should be made, particularly in terms of results, impact and outcomes
- It often relies on an entrepreneurial, rather than an economic, perspective
- It should also identify constraints that need to be overcome.

The business case precedes development of the *economic, financial and environmental case* - which identifies both the benefits and the costs. If too much attention is given at the beginning of a project lifecycle to these issues there will be a risk that the analysis will focus on why projects cannot go ahead rather than thinking about how to *overcome* economic, financial and environmental constraints.

In the context of STI investment, the foundation of a good "business case" is that a proposition being put forward is:

- Desirable – that there is a need, and a demand, for the facility and the services and that it will deliver
  - "Value" to the investors and users
  - "Benefit" to the community in terms of employment and income
- Practical – it will be possible to deliver it, having regard to resource and institutional constraints
- Feasible – that it will be possible to generate income steams having regard to cost, risk and return.

The *essence* of a business case is the argument that it is worth doing and taking the time, effort and commitment to bring it to fruition. Some prospects and propositions may take many years to bring into reality - but there has to be a shared understanding and agreement that it is worth going ahead with – at least to the full feasibility study stage.

The Government, as an Investor, should be looking at proposals from a number of dimensions – in addition to market, management and financial feasibility. It should be interested in factors such as:

- Capacity and capability to work as a business "partner"
- Experience in working with investors
- The scope/scale
- Distinctiveness/uniqueness
- The demand - and where from
- Size of market - segments, source
- What are the constraints
- How much money is required and how will it be utilized.

Recommendation

Priority be given to STI investments in facilities and equipment where there is a demonstrable public benefit outcome and/or collective benefit between businesses and research institutions. Investment proposals should be supported by a solid *business case*

12.2 Capability, programs and program support

Responses provided to the Request for Information indicated that STI investments were required in the development of capabilities and programs in number of areas. Specific responses are provided in Part 4, Section 2.

Many comments related to long term commitment and for projects and programs and support for research infrastructure in the traditional sense – that is, meeting the costs of overhead and "back office" functions. There are a number of proposals for new research centres and institutes to continue with and sustain research effort.

To the extent that new research institutes and centres can encourage and consolidate current capability, they are to be welcomed. We have a concern however, with the apparent proliferation of institutes and would suggest that the opportunities for consolidation of research effort within existing institutes and centres be examined. This issue was raised in focus group discussion in both the heath services and manufacturing sectors.

A number of research institutes have come together to form "consortiums" to focus on research in specific areas. The Victorian Breast Cancer Consortium, for example, involves the active collaboration of several institutes. There is strong support for a similar arrangement for prostrate cancer.

Recommendation

The Department of State and Regional Development, in conjunction with industry, examine ways to consolidate and develop capabilities in the many manufacturing and health research centres located across the STI base.

12.3 Investment in people

During the survey many people and organizations commented that Victoria was losing ground because of an inability to retain skilled and qualified people and the diversion of research training effort in universities.

There is also a concern that people are not being trained in basic science disciplines that are appropriate to some areas of research and development. For example, students are no longer being trained in programming languages necessary for simulation and working with high performance computers.

In many parts of industry the focus of work effort is becoming increasingly task oriented with progressively less time being available for problem solving and research work. Case mix funding and associated targets has effectively eliminated the time that RMOs can devote to research work.

The progressive movement towards contract research, purchaser-provider arrangements and the creation of internal markets is a major challenge to innovative capacity in

organizations – both public and private. It is well understood that the market mechanism is very poor at creating a climate for innovation.

Traditionally, innovation has been considered to be a core competency of an organization. Organizations, both public and private are investing in strengthening core competencies and acquiring other capabilities through networks, alliances and other relationships.

In the context of the knowledge economy, professionals are being required to take greater responsibility for investment in their own skills and capability in order to contribute to the development of core capabilities. Organizations, both public and private, are becoming less inclined to invest in people as part of a life long career path.

The capacity of individuals to fund and finance their own ongoing professional development is constrained. An important role for the public sector is to provide assistance and support for promising scientists to develop and further their professional competencies. This can be done through scholarship and other forms of assistance.

Recommendation

> **Strategies to strengthen the Victorian STI resource base include provision for scholarships and other forms of assistance and support for scientists to develop and further their professional skills, capabilities and neworks.**

12.4 Information and knowledge dissemination

Notwithstanding the existing mechanisms for cooperation and collaboration, a great deal of Victoria's science, technology and innovation capability is generated and maintained in organizational "silos" with limited capacity for wider dissemination and sharing. Innovation is more likely to occur when people interact in an organization or network rather than working independently.

Many people commented during the Review about the difficulty of identifying what organization and which people are involved in particular areas of research and development. It is important to acknowledge, however, that knowledge of the location of capabilities does not mean that people will cooperate and collaborate. Collaboration must be accompanied by appropriate reward and incentive systems that encourage knowledge sharing and interaction rather than acting in isolation.

An important outcome of this Review is to provide an information basis that will provide guidance about STI capacity and capability and where its is located. There is little doubt that the capability is extensive and much of it is little known to people outside their organizational environments. It is important that this information base is kept up to date. A problem that we encountered in the Review was that available data bases are either incomplete, out of date, or both.

One of the most interesting, and important, aspect of the Review has been the identification of a very large amount of information that is available in published formats. Unfortunately, it is not brought together in any systematic way. The problem is exacerbated by the falling off in commitment to building and maintaining libraries – particularly in the public sector.

While it is possible to address the problem with structured databases, information should be disseminated by less formal means – such as the formal and informal communication networks of industry and professional associations and social interaction.

Recommendation

> **The Department of State and Regional Development provide sufficient resources to maintain and update the information base that will be delivered as part of this Review.**

Relationships between people and organizations are governed by market mechanisms, organizational structures ad community arrangements. An important part if the STI strategy should be to create a strong *sense of community* within the STI resource base. There is very little that government can do in this regard – except remove the impediments to the evolution of a community approach to the development of Victoria's STI capabilities.

Communities are not geographic clusters and they do not emerge automatically by co-locating people within "precincts". Whilst close proximity is an important aspect in the development of social capital, interaction can also be effective through ""virtual" mechanisms. In this regard, it is important to note that many Victorian based scientists are effectively part of a global research and development community.

Scientists with world-class reputations invest heavily in maintaining personal and organizational networks – apart from maintaining a stream of publications. Again, this is often expensive and can provide the basis for public sector assistance and support – provided that government does not "own the process".

12.5 Support for commercialisation

There are many issues that inventors and individual entrepreneurs have to address in extracting value from new technology. Generally speaking, value will be created when commercialisation takes place in a business environment with the necessary management and marketing infrastructure. The main issues relate to the level of interest and involvement in that business.

When an inventor can rely on the instruments of intellectual property protection to protect an invention from imitation, theory suggests that the inventor can appropriate a substantial fraction of the invention's market value. When property rights are weak (the normal case) the inventor's capacity to extract value are circumvented.[42]

In the case where an inventor has a patent, and little else, then the options for the inventor, including scientists in publicly funded research laboratories, are:

- Licensing the technology to established businesses that already have the necessary complementary assets in place
- Using the patent as collateral to raise debt funds to help develop a business organization to exploit the technology
- Exchanging the patent for equity in a start-up, equity funded business

[42] Teece, David J, "Design Issues for Innovative Firms: Bureaucracy, Incentives and Industrial Structure", in Alfred D. Chandler, et. al. *The Dynamic Firm: The Role of Technology, Strategy Organizations and Regions*, Oxford: Oxford University Press, pp 150-1

- Exchanging the patent for equity, or an interest, in an established firm.

A major problem that runs through all of these options concerns valuation of the technology. Most providers of funds will have experts evaluate the technology. In some cases this can create less than satisfactory situations for research scientists acting alone as they tend to lack the expertise to negotiate beneficial commercial outcomes, or worse, they could face a situation of leakage where the technology can be acquired from the inventor for very little cost.

More wealthy research institutes with university backing and/or an equity fund, can overcome this problem by signalling value to financiers and venture partners by providing collateral, performance guarantees and co-investing.

The only clear circumstances where the individual inventor can succeed alone is when:

- The technology is well protected by intellectual property law
- The technology can be transferred from the inventor to an organization
- The inventor already has great wealth.

It follows that an entrepreneur in a research environment may need some help.

The situation that prevails in relation to each commercialisation track, and the issues that arise, are summarised below.

Commercialisation Options - Current Situation and Issues - A Summary

Commercialisation Option	Current situation	Issues
Licensing the technology to incumbent firms who already have the necessary complementary assets in place	A major function of university technology licensing companies Universities have traditionally allowed commercialisation entities a monopoly on licensing arrangements: this has changed at the University of Melbourne Pharma companies establish relationships with Faculties and Institutes and look for easy pickings (reference often to "pirates") Projects that require substantial research beyond "proof of concept" may not get support – eg clinical trials	Commercialisation arms not very astute commercially. Many operate with public service culture Poor relationships of commercialisation companies with academic researchers. Some (few) companies are locating their operations in Faculties and Institutes Technology may be licensed too early in order to gain funds for current research program – may under state value Intermediary agencies have emerged that look at efficacy and support clinical trials [One in Melbourne that is actually a spin-out from Monash University]
Using the patent as collateral to raise debt funds to help develop an organization to exploit the technology	There are many commercial operations run through Research Institutes and Faculties Many ventures in this category are being "handed back" from commercialisation companies as it involves day to day management and operations Research Institutes and Faculties not generally set up to raise debt finance or access to tax concession benefits Individual academic entrepreneurs not skilled at preparing business cases for banks	Difficulty in running such operations on a commercial basis. It can be done, but requires professional support – marketing, management accounting, legal, etc. Commercial operations may impact on "core business" There are some companies that have successfully "spun out" from University Engineering Departments – but remain very closely aligned Presents an option for generating additional funding and supporting research effort and teaching
Exchanging the patent for equity in a start-up, equity funded firm	An approach that is sought by may academic entrepreneurs, particularly those interested in being involved in a business. Academic entrepreneurs at a disadvantage when negotiating with equity providers Equity funding is generally provided to support marketing – not further research There are many "brokers" emerging in the	There is not a shortage of funds for early stage commercialisation – issue is finding "good deals" Case for very early stage "bird seed" funding to confirm and secure IP Academic entrepreneur may require assistance in pr4paration of business pans to put to VCs – that emphasise market and marketability of products Need for "informed" and honest brokers to act between the academic entrepreneur and the equity

Commercialisation Option	Current situation	Issues
	market. Some are good, some actually harm the opportunity Equity can be diluted through recapitalisation Academic entrepreneur may be "edged out" of management position as company grows	provider
Exchanging the patent for equity in an established firm	Situation relevant for a major Institute with a product that can be developed as a joint venture – sharing risk and returns Commits to ongoing development of the product in the market	Look at business relationships of the major medical research institutes Ventures can be national and international Such arrangements may be necessary in order to capture benefits Australian Photonics represents a special case in this category

These issues need to be more fully explored as a basis for developing commercialisation strategies that are relevant and appropriate to particular commercialisation tracks that are being pursued.

An important issue concerns the need to develop commercial knowledge and understanding abount scientists and entrepreneurs. This does not mean that scientists should be involved in the "hands on" commercialisation process – but they should be knowledgeable about the process as a way of ensuring that the right questions are being asked and that their interests are being accommodated.

Recommendation

> **The STI strategy provide assistance and support for scientists in business planning, management and marketing as a basis for entering into business to commercialise their technologies**

12.6 Enhancing the role of industry associations

Traditionally, industry associations have focussed on seeking government subsidies and special favours that benefit their members. There is strong evidence that governments are becoming increasingly less impressed by the lobbying efforts of industry associations that aim, in effect, to distort competition.

In the current environment the role of industry associations is changing towards providing:

- A forum for exchange of ideas
- A focal point for overcoming obstacles to productivity and growth
- Taking the lead in such activities as establishing university based testing facilities and training or research programs
- Collecting cluster based information
- Offering forums on common managerial related problems
- Investigating solutions to environmental issues
- Organising trade fairs and delegations
- Managing purchasing consortia.

National industry associations are setting up state and regionally based forums to address these issues. The efforts of professional services firms to place a stake in this area are often seen as less than credible.

We believe that there is a need for industry associations to be developed that focus on the development and growth of industry sectors in Victoria. In our view, the Department of State Development should support the development of industry associations and professional networks in key industry areas as a means to facilitate cooperation, collaboration and community.

Support should be based on, where possible, increasing the capacity of existing organizations rather than creating new ones. The initiative should be industry based, with government involvement as appropriate: it should not be government directed.

Recommendation

> **The Department of State and Regional Development provide financial support and other assistance to facilitate the development of industry associations and professional networks established to promote cooperation and collaboration in key industry sectors within the Victorian STI framework**

We consider that investments in these areas will go a long way to supporting cooperation and collaboration and providing the foundation for developing and enhancing STI capacity and capability.

12.7 Developing a culture of "community"

In addition to encouraging collaboration among organizations, it is also important to ensure that the scientists located in Victoria are encourage to participate and contribute to a "science community". It has been observed that in the information age, the heightened need for fluid patterns of cooperation and the rapid spread of knowledge are bringing the concept of community back into the forefront.[43]

Knowledge workers in general, and scientists in particular, frequently need to cross the boundaries of the organization to do their work. However, formal organizations, through their emphasis on measurement and control, create barriers that impede cooperation and the free flow of information that is necessary to achieve productivity outcomes.

It is acknowledged that people have traditionally helped each other across the boundaries of an organization because they are members of the same "informal" organization – part of a network of specialists working towards a common purpose relating to the creation of new knowledge.

It is important the mechanisms be established that support community interest and interaction. In this regard we see the establishment of an Internet Service Provider (ISP) for the Melbourne STI Community as being an important initiative.

The STI ISP would allow access to information and databases relevant to the development of STI resources. It would also provide for establishing relationships between the many people and organizations involved in science, technology and innovative effort.

[43] Hesselbein, Frances et al., *The Community of the Future*, Drucker Foundation Future Series, San Francisco: Jossey Bass, 1997, pp127-128

Recommendation

An ISP be established to support and promote Science Technology and Innovation in Victoria.

12.8 The role of government

Governments have recognised the importance of cooperation and collaboration between research organizations, universities and business for innovative effort through support for cooperative research centres. This support is often in the form of "structural capital" – to ensure that robust management and organization arrangements are in place.

Government also has a role to ensure that:

- There is a supply of high quality inputs such as educated people and physical infrastructure
- IP can be protected, and protection can be enforced
- Anti-competitiveness legislation and state policies do not work against the creation of collaborative and cooperative arrangements on a regional, national and international basis
- Taxation and infrastructure financing policies do not discourage private innovation investment in Australia
- People in public sector research organizations are not disadvantaged in commercial negotiations due lack of knowledge and less than full disclosure.

It is not the role of government to "second guess" or direct commercial investment decisions. However, government should be increasingly seen as a "partner" in the investment decision-making and delivery process. This is occurring in Victoria with the Bio 21 initiative.

We see the most important role of government in assisting and supporting the mechanisms for sustained and ongoing cooperation and collaboration between research organizations, universities and businesses. In this regard, we are strongly of the view that *Organization Matters*.[44]

[44] This is the subject of current research being undertaken by Howard Partners in relation to the development of management arrangements for cooperation and collaboration between Departments and Agencies.

Part 3: STI Capability in Specific Areas

1 Introduction

The purpose of this Part of the Report is to address the items in the project brief that relate to providing:

- Authoritative information to underpin the assessment and selection of infrastructure projects for funding through the Government's program ***Investing in Innovation***
- Information on resources available for use by industry and research organizations
- An information base for Australian and global businesses seeking a high technology location for investment:

Material is also provided to meet those elements in the project brief that required

> . . . the Review cover research infrastructure in universities, CSIRO facilities, DSTO, State Government research institutes and facilities and other research organizations, both privately and publicly funded.

The information is presented in terms of capabilities that exist in STI output categories. It is sourced from material provided in the "Request for Information", our own research, including the capability survey and from focus group discussions, and analysis of data provided from the Australian Bureau of Statistics.

The focus of the material is on overall capacities and capabilities. It provides information about what is being done in the main output areas and the scope and scale of activity. More specific information on resources and capacity is provided in Volume 2 of the Report *The Compendium of Research and Development Organizations in Victoria* and in the STI Database.

The information that is assembled is extensive and provides a detailed insight into Victoria's STI resource base. However, the extent to which it can be used in the process of selecting projects for STI investment will be influenced by the criteria on which those investment decisions are based. Nonetheless, the information that is provided in this part points to areas where Victoria has substantial strengths in its STI capability and, to the extent that investment will be based on doing what Victoria is currently do well, rather than what others are doing well (or better) at, there are some important issues to be considered.

In particular, the information reveals that Victoria has a very strong capability in the areas of plant and animal production, manufacturing, information and communications and medical and health services. In all of these areas there is a substantial emerging technology and "knowledge" components – reflected in the information about fields of research in each of the output areas. Application of these technologies may require investment in production areas that are capital intensive. There are many suggestions in Part 4 that concern "scale-up" requirements.

Research undertaken in other forums indicates that agriculture and manufacturing *do* have a future: that future lies in the application of new technologies and the adoption of a *interdisciplinary* approach to technology development and innovation. However, as we have indicated in Parts 1 and 2, innovation leading to growth in employment will require actions and initiatives to support cooperation, collaboration and networking with industry as well as ensuring that information, advice and assistance is available to ensure that opportunities are not lost.

2 Defence

2.1 STI Capabilities

The DSTO provides a capability in Victoria with a focus on defence industry. It is located adjacent to the Boeing facility at Fisherman's Bend. The capabilities of the DSTO Maritime and Aeronautical Research Laboratories is summarised below.

DSTO Laboratory	Research Expertise
Micro Electro-Mechanical Systems (MEMS)	Design of MEMS devices for ADF requirements. Characterisation of sensor response. Ability to do field trials on operational equipment. Emphasis on commercialisation of DSTO sensor research.
Aircraft and Structural Testing Laboratories	Tests may be under static or fatigue loading and may be at ambient environmental conditions or under controlled temperature and/or humidity conditions. Static tests may be to proof, ultimate or failure loads, or to lesser loads for strain surveys. Fatigue tests may apply aircraft manoeuvre loads, generally accelerated from real time, or may apply buffet loads in real time and in combination with manoeuvre loads. Test articles range from complete aircraft structures to large components of aircraft structures down to small components and specimens in testing machines. Tests on complete aircraft structures and large components are performed in large purpose-built rigs with multiple loading channels

The Australian Maritime Engineering CRC is closely associated with these organizations. The CRC has the following research focus.

Centre	Research Expertise
Australian Maritime Engineering CRC	Naval architecture, maritime engineering, offshore engineering, ship and other marine structures and materials, hydrodynamics, ocean engineering, computer and physical marine modelling.

2.2 Investment

The presence of the DSTO in Victoria provides a capability in the Defence area. Information on research and development investment is summarized below.

Table 5: Defence - Research and Development Expenditure 1996-97

Socio Economic Objective	Common-wealth Government $'000	State Government $'000	Higher Education $'000	Business $'000	Private Non-Profit $'000	Total Expenditure $'000
10100 Not Classified				53,823.0		53,823.0
10101 Electronics			289.5			289.5
10102 Surveillance			657.6			657.6
10103 Weapons systems			22.8			22.8
10105 Materials	120.5		180.8			301.4
10199 Defence i.e.	76,298.3		130.3			76,428.6
	76,418.9	0.0	1,281.0	53,823.0	0.0	131,522.9

The data points to a substantial amount of expenditure that has not been more finely classified in returns provided to the ABS. However, the presence of the DSTO would be reflected in the high levels of private investment through collaborative and contract arrangements.

2.3 Capability Indicators

The research capability in the Defence output category is summarized below.

Table 6: Research Capability in Defence

Fields of Research	No of Capabilities Identified	Total Capability Level	Average Capability	No of FOR classes	Count of Orgs
Applied Sciences and Technologies	6	24	4.0		
General Engineering	3	12	4.0		
Information, Computer and Communication Technologies	18	72	4.0		
Physical Sciences	3	12	4.0		
	30	120	2.7	11	3

Although there are only three respondent organizations, the research capability is heavily concentrated in the areas of information, computer and communication technologies. This points to strengths in the electronics sector that focuses on defence contracts.

3 Plant and Animal Production

3.1 STI Capabilities

Victoria has a well established and extensive STI capability in animal and plant production. The State Agriculture Research Institutes are complemented by CSIRO business Units, CRCs and University Research Centres

Information on the operations and interactions of these organizations is provided in Volume 2. Summary information is provided below.

- **Agriculture Research Institutes**

Institute	Location	Capability Overview
Arther Rylah Institute for Environmental Research	Heidelberg	ARI is the research base for the Flora and Fauna Program of NRE. ARI staff have expertise in major groups of native flora and fauna and a range of ecological processes. Staff include acknowledged experts in broad scale flora, fauna and ecological surveys, inventory, assessment and biological monitoring, management of threatening processes, recovery plans for threatened species, sustainable forest management, land management planning and community involvement in biological conservation processes.
Centre for Land Protection Research	Bendigo	Both directly and indirectly through research outcomes and training in the following: Catchment based GIS modelling; Enhancement of GIS databases; Natural resource mapping technology; Dryland salinity processes; Land and water management technology, including the development and targeting of catchment-specific salinity treatment measures/strategies; Land capability/suitability assessment techniques and data sets; Regional planning technology (incl. rural demographics and projections of change, etc.); Social impact assessment; Groundwater resource assessment; Processing and application of geophysical and other remote sensing data sets; Salinity assessment technology (incl. risk); Soil monitoring and management; Groundwater database for dryland salinity research; Soils database; Decision support system for native vegetation; Comprehensive computerised photograph library.
Centre for Tree Technology	Heidelberg	CFTT manages chemical and plant science laboratories at the Arthur Rylah Institute, and new laboratories have just been constructed at the Creswick campus of the University of Melbourne. The laboratories are used primarily for research purposes, and for a soil/plant/water/pest/disease diagnostic service for clients in both the native forests and plantations sectors. CFTT has been instrumental in assisting Government in attracting substantial private sector investment in blue gum plantations in several parts of Victoria. The Centre commenced its R & D on blue gum plantations in 1988, and state-wide research trials established and monitored by CFTT is proving to be a valuable investment by the State Government in collaboration with the Commonwealth Government and the private sector.
EllinbankDairy	West Gippsland	Agriculture Victoria Ellinbank offers through its staff the creation of new knowledge which is objective, science-based and client-focused, to enable the dairy industry to improve its international competitiveness. AVE also helps build STI capacity through training of undergraduate and postgraduate students.

Institute	Location	Capability Overview
Institute for Horticultural Development	Knoxfield	IHD provides State-wide and National R,D & E services for temperate horticultural industries, by: ▪ Developing smart diagnostic probes for use by quarantine agencies to detect new pests and diseases ▪ Integrating post harvest science and engineering for handling and transport of fresh produce ▪ Development and implementation of Best Practice, Research to Practice, adoption training programs. Engaging in on site training of postgraduate students from Victorian Universities in plant health and plant production
Institute for Integrated Agricultural Development	Rutherglen	AV-Rutherglen contributes to Victoria's science, technology and innovation capacity through research outcomes derived from the use of a modern analytical chemistry and microbiology laboratory together with glasshouse facilities. Together these facilities provide the means of fulfilling important outcomes that enable regional and statewide decisions to be made that assist in the protection of our soil and water resources. Capability to perform unique animal feed conversion studies using a newly constructed state of the art beef feedlot that provide an opportunity to realise the genetic potential of statewide animal breeding programs. A meat quality science laboratory that enables the assessment of meat products using consumer panels further supports these outcomes
Institute of Sustainable Irrigated Agriculture	Tatura	The Institute of Sustainable Irrigated Agriculture is the major research, development and extension institute in Victoria servicing the needs of sustainable irrigated agriculture. The Institute develops basic knowledge and understanding of irrigated agricultural production systems in high value horticulture, dairying and cropping, and the natural resource management processes associated with these industries. The Institute provides management, technical and economic support to the planning, implementation, monitoring and evaluation of land and water management plans in Victorian irrigation areas using advanced expertise in land capability mapping, geographic information systems, natural resource management and remote sensing technology.
Keith Turnbull Research Institute	Frankston	KTRI has a world-renowned reputation within the area of pest plant research. Recent changes have seen our research programs expand into the management of a range of agricultural and environmental pest plants and invertebrates KTRI holds Victoria's only Level II Quarantine facility, which allows the importation and study of a range of biotic agents under quarantine conditions.
Marine and Freshwater Resources Institute (MAFRI)	Queenscliff and Snob's Creek	MAFRI's distinctive range of specialist scientific expertise and equipment, is such that it has the capacity to undertake a diverse range of sophisticated data collection, analysis and interpretation services across all fisheries and most water related disciplines. It is Victoria's leading aquatic research institute and is the leading State-based institute, in its field, in Australia. The core skills offered by the Institute include: Marine and freshwater fisheries biology, assessment and modelling; Marine and freshwater ecological research and environmental assessment; Aquatic chemistry; Marine GIS; Aquaculture research and extension; Ecotoxicology and oil testing; Population modelling; Resource management data bases and systems; Community, schools and tertiary education and training; Marine and freshwater technical operations and small vessels
Ovens Research Station	Ovens	Ovens Research Station is a 'campus' of IHD rather than a 'stand alone' institute. Equipped to provide direct research outcomes related to production, harvest, distillation and analyses of existing and new essential oils from crops requiring steam distillation.

Institute	Location	Capability Overview
Pastoral and Veterinary Institute	Hamilton	Agriculture Victoria - Hamilton is the main agricultural facility in high-rainfall, temperate Australia undertaking research for the broadscale grazing industries, especially wool and meat sheep, and beef cattle. The core business of AV-H is pasture plant breeding and improvement, nutrition and genetic improvement of sheep and beef cattle and the development of sustainable production systems. A key function of the institute is to integrate pastures, crops, animals and farm forestry into farming systems.
Plant Biotechnology Centre	Bundoora	DNRE/Agriculture Victoria's Plant Biotechnology Centre at La Trobe University has a strong research base with skills in plant biotechnology and associated biological sciences. The staff have extensive experience and strong discipline training in plant cell and molecular biology, molecular marker and gene technologies, bioinformatics and plant genomics. AV's Plant Biotechnology Centre is the State-leader in the development and deployment of genomics, transgenic and molecular marker plant technologies for plant improvement, is nationally competitive in the strategic area of molecular plant breeding, and is the world-leader in pasture plant biotechnology. DNRE/Agriculture Victoria's Plant Biotechnology Centre has significant infrastructure and systems to undertake high-throughput structural and functional plant genomics research.
State Chemistry Laboratory	Werribee	SCL provides specialist analytical, research, investigation and consultancy services in chemistry and related sciences, focused on agricultural, environmental and food processing issues. SCL is one of only a very few institutions in Australia which plays a major role in the continued development and provision of a wide range of analytical services to support agricultural, food processing and natural resource based industries.
Sunraysia Horticultural Institute	Mildura	The Sunraysia Horticultural Centre is a research, training and industry development institute for horticulture specialising in the irrigated crops of the region particularly grapes, citrus and vegetables.
Victorian Institute of Animal Science	Attwood, Werribee, Frankston	The Victorian Institute of Animal Science is the major animal research and diagnostic facility in the State of Victoria. The work of the institute covers all aspects of veterinary medicine, animal production, genetics and husbandry with a current emphasis in dairy genetics, molecular vaccines against parasites, animal welfare and behaviour, pig nutrition, veterinary diagnostics, meat quality, food safety and feral pest control.
Victorian Institute of Dryalnd Agriculture	Horsham	Provider of training and skill development for rural industry in Victoria through collaboration with University of Melbourne (through JCCI) to develop MSc, PhD students by industry placement and supervision in rural locations (Horsham and Walpeup, with JCCI increasing placement of students at other AV locations) VIDA contributes, with AV Rutherglen and CLPR, to development of sustainable cropping and land management practises across rural Victoria. The full value of new crop cultivars from VIDA's breeding programs can only be realised if they are presented to growers with well-developed agronomic packages, and as part of a sustainable crop/pasture rotation. The approach is multi-disciplined, involving soil science, pasture and crop agronomy, farm economics, and computer simulation.

▪ CSIRO Business Units

Division/Unit	Location	Capability Focus
Animal Health	Geelong, Parkville, Werribee	CSIRO Animal Health plays a vital role in maintaining Australia's capability to quickly diagnose exotic (foreign) and emerging animal diseases. This is achieved through ongoing research programs to develop the most sensitive, accurate and timely diagnostic tests, which are critical to the success of any eradication campaign in the event of a disease outbreak. CSIRO Animal Health also undertakes research to develop new diagnostic tests, vaccines and therapeutics for endemic animal diseases of national importance. Major diseases of livestock, aquaculture animals, and wildlife, are studied.
Forest Products	Clayton	The Division delivers research outcomes for forest owners and growers, contractors, sawmillers, wood and paper product manufacturers, timber designers, specifiers and users, and for development assistance agencies, policy makers, forest regulatory agencies and the community.
Molecular Science	Clayton South, Parkville	Molecular Science combines chemical and biological expertise to provide a broad research base for Australian industry, flexibility for strategic research and the ability to exploit emerging trends in science. Its seven Research Programs are: Specialty Chemicals and Environmental Technologies; Protein and Pharmaceutical Sciences; Applied Chemistry and Polymer Science; Biotherapeutics and Delivery; Molecular Discovery and Processing, Biomaterials and Bioengineering; and Instrumental Methods.
Plant Industry – Horticulture Unit, Merebin	Clayton, Merbein	CSIRO Plant Industry carries out research in the plant sciences to make Australia's agri-food, fibre and horticultural industries more profitable and sustainable. A major focus is on improving production efficiency and reliability while maintaining the natural resource base. We are placing increasing emphasis on product quality related objectives for the processing and manufacturing sectors and the development of novel plant products. Our research also contributes to conservation of biodiversity in the Australian flora and the implications of global climate change for natural and agricultural ecosystems.

▪ Cooperative Research Centres

Centre	Capability Overview
CRC for Viticulture	Grape quality attributes, grapevine pests and pathogens; gene technology (grapevines and yeast), precision viticulture, grapevine water relations; grapevine secondary metabolism; grapevine physiology; viticultural education.
CRC for Molecular Plant Breeding	Plant breeding, molecular biology, genetic engineering, plant pathology, plant nutrition, plant stress tolerance, cereal chemistry, plant physiology, biochemistry and genetics.

▪ University Research Centres

Host University		Capability Overview
Centre for Animal Biotechnology	University of Melbourne, Faculty of Veterinary Science	The Centre for Animal Biotechnology (CAB) has gained an international reputation for its efforts in basic research of the immune system of large animal (sheep, cattle, pigs). As an internationally established world centre in this area, the CAB has been able to attract significant industry funding, in particular in the area of vaccine research. In addition, the CAB has been able to attract high quality peer-reviewed grants from the ARC and National Health and Medical Research Council. is a major centre in Australia for post-graduate training in large animal research, providing high quality graduates for employment in basic and applied veterinary sciences as well as medical research. Many graduates also benefit from extensive collaborations with industry partners.
Centre for Equine Virology	University of Melbourne, Faculty of Veterinary Science	The CEV has a very strong record of achievement in PhD training in Veterinary Virology. Virus diseases continue to impact greatly on the health and well being of man and animals and the discipline has for many decades been at the forefront of contemporary biological research encompassing all of the advances in molecular and recombinant DNA technologies. While the research focus is on equine viruses the training is generic, broad based and highly portable. Scholarships are available.
Dairy Process Engineering Centre	Monash University, Faculty of Engineering	The Dairy Processing Engineering Centre is an industry centre with core funding provided by the Dairy Research and Development Corporation. It is located within the Department of Chemical Engineering at Monash University in the Werribee Food Science and Technology Precinct. The Centre's mission is to enhance the profitability and sustainability of the Australian dairy industry through leadership in the development and application of process engineering skills. The organization places a strong emphasis on linking industry research with training and educational programs. These links are facilitated, on the one hand, by a series of rolling research projects on select topics of key importance to the dairy industry (e.g. the Cleaning Systems project spanning 98/99), and on the other hand, a program of workshops and seminars to disseminate research findings to identified stakeholders.
Joint Centre for Crop Improvement	University of Melbourne, Institute of Land and Food Resources	The JCCI is an unincorporated collaborative venture between The University of Melbourne and Agriculture Victoria (AV). The Department of Crop Production is the University's host Department for the JCCI and the Victorian Institute for Dryland Agriculture (VIDA) at Horsham is the Director's primary location. JCCI has been an effective vehicle for its two partners gaining infrastructure. For example, through the JCCI the University and AV have gained two large glasshouses (based at VIDA) and a third (to be erected) at Longerenong College and a well equipped laboratory for molecular plant breeding at Parkville. The JCCI also had a significant role in the recent purchase of additional land to the west of VIDA site at Horsham by AV
Joint Facility for Food and Animal Research	University of Melbourne, Institute of Land and Food Resources	The JFFAR infrastructure support intensive physiological research on a multi-disciplinary basis from cellular to whole animal levels in areas relating to improvement of animal food (milk meat) and fibre production systems and product quality. Development and application of biotechnological approaches and tools for improvement of livestock production and raw qualities.
Plant Cell Biology Research Centre	University of Melbourne, Faculty of Science	The Plant Cell Biology Research Centre is a Special Research Centre within the School of Botany at The University of Melbourne in Australia. It has world class expertise in molecular and cellular biology of breeding systems and the biology and chemistry of complex carbohydrates. These are also important in industries including agriculture, food, forestry, nutrition and horticulture.

3.2 Investment

Information regarding investment in research and development in terms of the socio-economic objectives relating to plant and animal production is provided below.

Table 7: Plant and Animal Production - Research and Development Expenditure 1996-97

Socio economic objective	Commonwealth Government $'000	State Government $'000	Higher Education $'000	Business $'000	Private Non-Profit $'000	Total Expenditure $'000
Plant production and primary products						
Field crops	122.7	18,465.9	3,402.1	4,551.0	0.0	26,541.7
Horticulture	3,488.0	18,743.2	1,059.1	3,829.0	0.0	27,119.3
Forestry	4,805.2	5,580.0	3,779.3	0.0	0.0	14,164.5
Primary plant products	0.0	1,144.2	148.1	0.0	0.0	1,292.3
	8,415.9	43,933.3	8,388.6	8,380.0	0.0	69,117.9
	12.2	63.6	12.1	12.1	0.0	100.0
Animal production and primary products						
Livestock	20,181.7	33,064.0	9,460.6	3,148.0	0.0	65,854.3
Pasture, browse and fodder crops	0.0	2,943.1	333.9	0.0	18.0	3,295.0
Fishing	1,822.5	4,862.8	610.8	0.0	0.0	7,296.0
Primary animal products	498.9	0.0	263.1	1,383.0	0.0	2,145.0
	22,503.0	40,869.9	10,668.3	4,531.0	18.0	78,590.3
	28.6	52.0	13.6	5.8	0.0	100.0

Victoria has a particularly strong dairy industry, as well as oil seeds, horticulture, grains, forestry and food science.

The data point to the high level of investment by the State Government, through the Agriculture Research Institutes and by the Commonwealth through the CSIRO. There is also a high level of commitment by the higher education sector, but the contribution of industry is relatively low. There is strong collaboration between the Commonwealth and State sectors. The Knoxfield and Werribee sites offer critical mass and strong technical depth.

3.3 Capability indicators

The rating of capability in the Plant and Animal Production Sectors based on the survey returns is summarised below.

Table 8: Research Capability in Plant and Animal Production

Fields of Research	No of Capabilities Identified	Total Capability Level	Average Capability	No of FOR classes	Count of Orgs
Animal Production and Primary Products					
Agricultural Sciences	6	11	1.8		
Biological Sciences	8	10	1.3		
Medical and Health Sciences	6	8	1.3		
	20	29	1.5	16	3
Plant production and primary products					
Agricultural Sciences	6	23	3.8		
Applied Sciences and Technologies	3	11	3.7		
Biological Sciences	2	8	4.0		
Social Sciences	1	3	3.0		
	21	69	3.3	15	4

The survey data point to strong capabilities in agricultural sciences relating to plant production and primary products. The organizations that responded did not see strength in research capability in animal production.

3.4 Comment

Agriculture Victoria is looking for ways to leverage the R&D dollar, eg via pooling of co-investment partners, or matching State Government funding via RDCs or other grants programs (eg ARC SPIRT). The agency is an active participant in several Cooperative Research Centres.

The University of Melbourne/ILFR provides very practical training to students and facilitates their interaction with an industry environment. The links to AgVic make training more applied than otherwise possible, with flow-on benefits in terms of labour flows, mobility within the industry etc.

The Ingredients Centre has developed planning processes that focus on issues that are considered by industry to be potential risks/issues 3 - 5 years forward, as well as on current needs, and as such involves industry (funding) in some 80% of its activities. Research is intended to develop dairy-derived product for global markets, so also involves international partners (eg Irish for milk powder, US for pizza toppings) thus adding to the overall markets/competitiveness of the Victorian dairy industry. State Government assurance of a strong underpinning science base was seen as key to these activities.

Food Science Australia (FSA) takes an integrated approach across the food supply chain and, though also operating in Brisbane and Sydney, has a strong Victorian base. FSA also has international partners in Korea and Japan.

3.5 Issues Raised During Focus Group Meetings And Consultations

A number of issues have been identified that impact on capacity and capability for innovation in agriculture.

- While the purchaser-provider arrangements at Department of Natural Resources and Environment are increasing commercial focus and accountability of research and favouring co-investment models, there is a risk that the absence of some “block” research funding will limit capacity for exploring new and emerging research areas
- Rationalisation in the industry and the research profile is increasing pressures on the Victorian infrastructure. For example, AgVic is now doing some projects that would previously have occurred in Tasmania
- The costs/required scale of some research programs, and a focus on short term funding, means that AgVic may only contribute a small percentage - yet it may be a key part
- Industry will co-invest where it sees the best science being done. There is, however, a need to be able to attract and retain the best scientists. There are some gaps in the current profile
- Education and training facilities are increasingly resource constrained. For example, needing to resort to unusual programs (such as ARC REEF) to obtain glasshouse facilities
- University of Melbourne students are now required to commence their theses with a description of the utility, the commercial significance of their project to industry, relevant markets, patterns of commerce etc, giving a very practical and purpose-oriented approach to project design and training

- Where a company such as Monsanto takes a 'build a supply chain' approach to structuring its capabilities, Victoria has a generally disconnected system which could benefit from stronger 'direction' and networking.

3.6 Initiatives Proposed During Focus Group Discussions

A number of specific initiatives have been identified in discussion during the Review, including:

- Increasing the mechanisms and support whereby AgVic can tap into some large-scale research initiatives that it could not independently justify, by participating in national projects, for example, biotech for pastoral industries
- Attracting industry to Victorian research sites, even if not 'head offices', to further increase alignment of research with market needs and therefore potential co-investment funds
- Infrastructure support to attract and retain core experts who can then be 'grant-winners' and 'industry-attractors'
- Funding more glasshouses for plant biotechnology for multiple users
- State support to assist spin-off companies, especially incubation and pilot scale activities, where pilot facilities could have multiple users
- Mechanisms for staff exchanges to industry, and to enhance mobility of staff across various aspects of an industry or, if skilled in a technology, across industries.

There is some potential to increase efficiency of R&D across various industries by also building infrastructure around fundamental platforms (for example, bioinformatics), from which several rural industries will benefit. This may sometimes require coordination with other States (or even New Zealand) as competition in the form of duplication will make Victoria's position weaker, not stronger.

There is a strong need to create priority-setting and evaluation mechanisms to ensure a focus on outcomes, especially where industry associations do not do this and where executive discretionary time has been reduced such that this no longer occurs in an 'ad hoc' fashion. There is an opportunity for government to broker industry forums to identify strategic priorities, to help STI practitioners.

There is a potential role for government to take a 'supply chain' approach to Victoria's Agricultural and Rural industries, by industry, to facilitate more integrated systems. There were suggestions for a new structure, such as an unincorporated joint venture, to do this. It could be based on platform technologies, for example, genomics, where there could be some rationalisation/aggregation of users, and it could be linked to medical sciences also. (Similar to a model from Saskatoon, Canada).

4 Mining and minerals

4.1 STI Capability

Victoria has a strong STI capability in mining and minerals. This is indicated by the strong research, development and innovation capability and the continuing commitment for the major mining companies to keep a strong presence in Victoria.

A number of mining companies have been progressively scaling down their own research and development capabilities and entering into contracts with university research centres and laboratories.

A summary of capabilities is provided below. More detailed information is provided in the Compendium of Research and Development organizations.

- **CSIRO**

Division/Unit	Location	Capability Overview
Petroleum Resources	Glen Waverly, Syndal	CSIRO Petroleum Resources develops and applies knowledge in a range of science and engineering fields to reduce costs, increase new discovery rates and improve the percentage recovery of known resources in the oil and gas industry. These goals are achieved by application of world best practice and development of strategic relationships within the Australian Petroleum CRC and other national and international peer groups, and service and operating companies. The results of research are applied within the petroleum, energy, mining and mineral processing sectors.
Minerals	Clayton South	CSIRO Minerals' raison d'etre is to provide the critical research, development and commercialisation support necessary for the Australian mineral processing and metal production industries to remain globally competitive. It achieves this through the innovative application of its staff's mineralogical, metallurgical, chemical, physical, engineering and mathematical skills and experience, and of its cutting-edge facilities for mineral characterisation, process modelling and diagnosis, and pilot plant construction and operation. These skills and equipment are applied from the micro (viz. atomic and molecular) to the macro (viz. plant) level to provide the required solutions to industry's complex problems.

- **Cooperative Research Centres**

Centre	Capability Overview
GK Williams CRC for Extractive Metallurgy	The Centre has the capability to carry our short, medium and long term research and consulting projects in areas including (but not limited to); laser based flow diagnostics, computational fluid dynamics, process development, process analysis and modelling, high temperature chemistry, refractory analysis, heat flow and refractory cooling.
Australian Geodynamics CRC	Structural geology, geochronology, seismology, tectonics, non-linear dynamics, computer modelling of coupled processes, geology modelling and computer visualisation.

- **University Research Centres**

Host University		Capability Overview
Advanced Mineral Products Research Centre	University of Melbourne, Faculty of Science	The AMPC is multi-disciplinary in nature, combining skills of staff and students in the School of Chemistry and the Departments of Mathematics and Chemical Engineering. It is a Special Research Centre of the Australian Research Council (ARC). The Centre exploits existing expertise in colloid and surface science, interfacial continuum mechanics and rheology, all set within a process engineering framework The Centre aims to consolidate research and technological leadership to support the strategic goals of value-added products of the Australian minerals industry..
Australian Crustal Research Centre	Monash University, Faculty of Science	The Australian Crustal Research Centre is concerned with the structural and tectonic evolution of the Earth's crust, with a particular focus on orogeny. The original aims of the ACRC were to establish a reputation as a field-based research centre concerned with structural geology and tectonics.
Minerals Industry Research Institute	University of Ballarat	MIRI conducts research in mineral-related projects, in collaboration with Australian and overseas Universities. Institute publications in international journals, and sponsorship of industry short courses, conferences and workshops raise the research profile of the University of Ballarat in the minerals industry.
Victorian Institute of Earth and Planetary Sciences	University of Melbourne, Faculty of Science	The primary objectives of VIEPS are to investigate and support: ▪ inter-disciplinary programs in geological, geophysical and atmospheric sciences to create a unified approach to the study of earth and planetary sciences. ▪ coordination of facilities and staff between the VIEPS partners to enhance their teaching and research programs by more effective use of their resources. ▪ collaboration between private industry, the VIEPS academic institutes and state organizations in order to keep teaching and research programs in touch with industry needs and developments. The co-operation, collaboration and academic expertise within VIEPS is the product of a strong commitments by industry, government and the participating universities to improved education and relevant research.

The etxnet to which these centres and institutes collaborate is not clear.

4.2 Investment

Information on expenditure on minerals exploration and first stage processing is provided below.

Table 9: Mining - Research and Development Expenditure 1996-97

Socio economic objective	Commonwealth Government $'000	State Government $'000	Higher Education $'000	Business $'000	Private Non-Profit $'000	Total Expenditure $'000
Exploration	885.0	4.1	393.9	0.0	0.0	1,283.0
Primary mining and extraction	67.7		3,980.8	0.0	0.0	4,048.5
First stage treatment of ores and minerals	17,933.0	0.0	104.0	14,951.0	0.0	32,988.0
	18,885.7	4.1	4,478.7	14,951.0	0.0	38,319.6
	49.3	0.0	11.7	39.0	0.0	100.0

The data point to a substantial investment by the public sector, through the CSIRO, and the private sector to research and development in treatment of first stage mineral ores and minerals

4.3 Capability Indicators

The one organization that responded to the survey reported an "average" capability level.

Table 10: Research Capability in Mining

Fields of Research	No of Capabilities Identified	Total Capability Level	Average Capability	No of FOR classes	Count of Orgs
Chemical Sciences	1	3	3.0	1	1

4.4 Comment

The past decade has been particularly difficult for the minerals industry on a global scale due to the combined pressures of depressed commodity prices, globalisation, the Asian crisis and the impact of the information technology industry (dot com companies). In response to this environment, companies have focused their attention upon creating shareholder value and growth through mergers and acquisitions rather than the traditional methods of increased exploration and investment in innovation.

In the past five years the industry has shifted its strategy of 'technological development' to one of 'fast follower'. As a result, corporate research groups have been downsized, technological development outsourced and exploration budgets slashed. These trends place pressure upon the STI infrastructure supporting the industry.

Victoria has strong historical links with the minerals and energy industry and indeed, Melbourne was once the industry's capital city, the location of corporate head offices and relevant supporting institutions in finance, education and training, and research and development. The fact that the Australian Minerals Industries Research Association (AMIRA) was based in Melbourne upon its conception in 1959 is evidence of the industry's base in Victoria.

The same cannot be said of the industry's role in Victoria and Melbourne today as its activities and centre have shifted out of Victoria and into Western Australian and Queensland. In particular, as companies' exploration and mining activities have gravitated to Western Australia and Queensland, so too have the related service industries and STI Infrastructure. For example,

- Queensland is home to the Julius Kruttschnitt Minerals Research Centre (JKMRC)
- CSIRO has moved a significant proportion of its related activities into these States
- AMIRA has opened offices in Brisbane and Perth.

Furthermore, the Western Australia and Queensland State Governments have been proactive in their efforts to attract companies in the minerals and energy industry and in establishing supportive STI infrastructure. Concurrently, Victoria was regarded by the industry as the "pariah" state, particularly for exploration.

Significant minerals and energy expertise and STI infrastructure still remain in Victoria. This infrastructure is particularly centred on processing and is well networked, with a

concentration of facilities in Clayton (see initiatives below). Other components of minerals and energy related STI infrastructure include:

- The Victorian Institute of Earth and Planetary Sciences (VIEPS), a cooperative education and research institution between Melbourne, La Trobe and Monash Universities which aims to coordinate facilities, staff, research, education programs and interaction with industry
- Cooperative Research Centres with groups in Melbourne including:
  - Clean Power from Lignite
  - Australian Geodynamics (due to be disbanded in July)
  - G K Williams Centre for Minerals Processing
  - AJ Parker CRC for Hydrometallurgy
- CSIRO Minerals and Petroleum also have Divisions in Melbourne.

The industry feels that the State Government ignores their needs and underestimates their contribution stating that, 'Victoria needs us more than we need Victoria,' and that it is really inertia that has prevented the remaining STI base from locating elsewhere.

A 1994 State Government plan that has delivered a major boost to exploration is the Victorian Initiative for Minerals and Petroleum (VIMP) that provided $25.5 million for airborne surveys, geological mapping and database preparation. This program initially boosted exploration in the State from $12.2 million in 1992/93 to $51.9 million in 1996/97. Record low gold prices have caused a 12% decline in exploration in recent years, however, the Victorian exploration slump is less than the 18% decline experienced nationwide.

4.5 Issues Raised During Focus Groups And Consultations

There is an apparent lack of support for the industry in Victoria – tends to be regarded as a low tech industry, with attention and support moved to the 'new' industries. Government needs to develop some momentum in support for the industry, akin to the 'can do' attitudes of the Western Australia and Queensland State Governments. Some specific issues concern:

- There does not appear to be a 'voice' or 'champion' to promote and raise awareness of the industry in Victoria
- Location is not critical to the present, processing-focused STI infrastructure and without 'nurturing' this could be located outside Victoria in 10 years time
- There are substantial gaps in professional knowledge in key areas, gor example, refining technology and gas processing, as evidenced by recent events. Participants noted that it took a crisis of the scale of last year's power (gas) shortage for the State Government to develop an energy policy
- Implications of global warming, the Kyoto Protocol, and possible carbon credit trading.

Initiatives proposed during focus groups and consultations for improvement include:

- Purposeful promotion, branding and integration of the "Clayton Complex" of minerals processing and manufacturing STI infrastructure
- State investment in 'infrastructure attractors' (as for example, the synchrotron facility)

- Establish a second tier Stock Exchange, such as the Bendigo Stock Exchange, for start-up companies who wish to develop new ideas on a longer time scale than that of venture capitalists
- Promote greater awareness of the value of the minerals and energy industries. In particular, create an internationally recognised profile for Victoria's expertise in processing research, education and infrastructure
- Maintain the State Geological Survey and VIMP to provide up-to-date geological information to attract exploration and consequent industry development in Victoria.

5 Energy

5.1 STI Capability

In comparison to other output segments, STI commitment in energy is relatively small.

- **Cooperative research centres**

Centre	Capability Overview
CRC for Clean Power from Lignite	The properties and characteristics of lignite; ash and deposit formation, the chemistry and physics of coal processing, including coal drying, gasification and combustion; mathematical and physical modelling; and technology development for conventional and advanced cycles.

5.2 Investment

Information relating to research and development expenditure on energy resources and energy supply is provided below.

Table 11: Energy - Research and Development Expenditure 1996-97

Socio economic objective	Common-wealth Government $'000	State Government $'000	Higher Education $'000	Business $'000	Private Non-Profit $'000	Total Expenditure $'000
Energy resources						
Exploration	2,682.2	0.0	509.0	0.0	0.0	3,191.2
Mining and extraction	3,234.9	0.0	19.4	15,030.0	0.0	18,284.3
Preparation and supply of energy source minerals	336.4	0.0	134.5	0.0	0.0	470.9
Other	0.0	0.0	218.6	91.0	0.0	309.6
	6,253.5	0.0	881.5	15,121.0	0.0	22,256.0
	28.1	0.0	4.0	67.9	0.0	100.0
Energy supply						
Energy transformation	2,249.2	73.1	161.6	0.0	0.0	2,483.9
Renewable energy	64.3	0.0	382.2	1,253.0	101.7	1,801.2
Energy distribution	1,336.9	0.0	2,219.6	8,639.0	0.0	12,195.5
Conservation and efficiency	1,935.0	12.2	1,014.3	2,884.0	0.0	5,845.5
	5,585.4	85.3	3,777.7	12,776.0	101.7	22,326.1
	25.0	0.4	16.9	57.2	0.5	100.0

The data reflect a high level of investment in the business sector, which would include the commitments of privatised energy utilities.

5.3 Capability Indicators

Information about research capabilities provided by two respondents is provided in Table 12.

Table 12: Research Capability in Energy

SOE	Fields of Research	No of Capabilities Identified	Total Capability Level	Average Capability	No of FOR classes	Count of Orgs
Energy Resources						
	General Engineering	5	16	3.2		
		5	16	3.2	3	1
Energy Supply						
	Applied Sciences and Technologies	2	9	4.5		
	Earth Sciences	2	9	4.5		

SOE	Fields of Research	No of Capabilities Identified	Total Capability Level	Average Capability	No of FOR classes	Count of Orgs
	General Engineering	5	21	4.2		
	Mathematical Sciences	2	9	4.5		
		13	57	4.4	13	2

The two organizations that responded to the survey in relation to energy supply were of the view that there was a high level of capability in four key research fields relating to the industry.

6 Manufacturing

6.1 STI Capability

Victoria has a very strong capability in science, technology and innovation in manufacturing. It is reflected in a major commitment by the CSIRO, the universities and industry. In fact, a significant proportion of the STI infrastructure in manufacturing exists within private companies, and its benefits are captured directly by the company.

The CSIRO Business Units, University Research Centres and businesses are linked in a complex network of interaction, cooperation and collaboration. Summary information about capability is provided below. More detailed information is contained in the *Compendium* and in the *STI Database.*

- **CSIRO**

Division/Unit	Location	Capability Overview
Australian Automotive Technology Centre (A wholly owned subsidiary of CSIRO)	Preston	AATC helps component makers by making available the technology development resources of CSIRO and Cooperative Research Centres to assist Australian manufacturing operations in maintaining international competitiveness in quality, cost and technology. AATC is involved in research projects on automotive technologies that are likely to be used in the next generation of automobiles. Projects include motors for hybrid-electric cars, control systems, batteries, supercapacitors and fuel-cells. Working in partnership with component manufacturers, the aim is to provide uniquely innovative technological, cost-effective componentry to overseas customers.
Aerospace Optics Centre	Clayton	Aerospace Optics Centre provides business, government agencies and individuals with consultancy services, free advice and referral. Our major contribution is in provision of a fully integrated prototype design and manufacture facility for optical and opto-mechanical equipment. Indirectly the Aerospace Optics Centre has contributed to ST&I infrastructure by developing in collaboration with Integrated Spectronics Pty.Ltd. airborne spectroscopic equipment. One sensor is operated commercially throughout Australia by HyVista Corp. Data are used by companies, universities and public sector research organizations for geological survey, soil mapping, mineral mapping and exploration, renewable resource management, forestry and agricultural management and environmental monitoring.
Manufacturing Science and Technology	Clayton, Preston	Science and technology foci range from materials development, processing and characterisation, electrochemical technologies, micro manufacturing, plasma and laser processing, joining and cutting technologies, and surface engineering, through to pervasive technologies such as automation and real time systems, photonics and intelligent manufacturing systems.

Division/Unit	Location	Capability Overview
Food Science Australia (A Joint Venture between the CSIRO and the Australian Food Science Centre	Clayton South, Highett, Werribee	Food Science Australia's multidisciplinary skill base and knowledge of the latest developments in food processing technologies are unique in Australia. It works closely with a wide range of industries, including the dairy, meat, milling, baking, snack and fruit and vegetable processing industries, as well as with service providers to those industries, such as packaging, transport and storage companies. In association with CSIRO Divisions in the Food Processing Sector, Food Science Australia offers research and technical services which solve problems for the food industry at every stage of the processed food business system, from analysing consumer needs to product design, through production optimisation, transport and storage, to marketing and retail support. Although its main focus is on the food processing industries, Food Science Australia also contributes to other Sectors, particularly Meat, Dairy and Aquaculture, Field Crops and Horticulture.
Textile and Fibre Technology	Clayton South, Belmont	Delivering competitive advantage through Research, Development and Innovation, CSIRO Textile and Fibre Technology is one of the world's most respected textile and fibre research organizations. The Unit works with industry to understand commercial needs and develop customised solutions. It provides an extensive range or research, instrumentation, consulting and testing services. Its world class scientists are supported by leading edge industrial and research technology. We generate innovations in processing, product development and environmental analysis.

▪ Cooperative Research Centres

Centre	Capability Overview
CRC for Advanced Composite Structures	Design, manufacture and performance of composite structures and materials, aeronautical, materials and production engineering, process modelling computer-aided design and manufacturing, stress analysis, structural and environmental testing, resin chemistry, fire performance of materials.
CRC for Hardwood Fibre and Paper Science	Pulp and paper technology, physics and chemistry, chemical engineering, process and resource modelling, forest economics, tree physiology.
CRC for Bioproducts	Bioprocess Development and Engineering: laboratory to semi-commercial scale fermentation and product recovery, project engineering and economic evaluation. Structure and Function of Biomolecules: analysis of biomolecule composition, structure and functionality; modification of properties; characterisation of complex multicomponent systems. Molecular and Cellular Biology: plant cell and organ culture, genetic and environmental control of cell metabolism and secondary metabolite synthesis; foreign gene expression
CRC for Polymers	Polymer synthesis; chemical, physical, melt rheology and mechanical characterisation; predictive software for the simulation of polymer processing; recycling of plastic waste.
CRC for Intelligent Manufacturing Systems and Technologies	Manufacturing information systems, concurrent engineering, design for manufacture, production simulation and control, sensor fusion, signal processing, cutting, grinding and polishing, metal and plastics manufacture modelling, rapid prototyping.
CRC for CAST Metals Manufacturing	Casthouse technology, solidification technology, physical metallurgy of light alloys, casting processes, tooling technology, manufacturing systems, design and prototyping of light alloy castings.
CRC for International Food Manufacture and Packaging Science	Food science and processing; materials science and technology applied to smart packaging concepts; rheology of polymer melts; biological treatments for fibre recycling; neural networks applied to sensory manufacturing;

Centre	Capability Overview
	enzyme modification and processing; microbiology; bacterial molecular genetics; machine vision; distribution and logistics.

The CRC capabilities and focus also relate to the construction sector, particularly in cutting and joining technologies.

- **University based research centres**

Research Centre	Host University	Capability overview
Advanced Engineering Centre for Manufacturing	RMIT University	The Centre is a joint venture between RMIT University and the University of Melbourne established in 1993 to promote closer interaction between these universities and Australia's manufacturing industry. The Centre's education and training activities enhance the linkages between the universities and manufacturing industry. The Centre assists the continuous improvement of industry via a wide range of multi-disciplinary innovative education and training programs for both technical and management personnel in manufacturing industry, from 'shop floor to board room'. The Centre has an extensive program for training of shop floor personnel from most of Victoria's leading manufacturing companies in modern manufacturing techniques such as inventory management, work place organization, quality control, and related topics.
Australian Pulp and Paper Institute	Monash University, Faculty of Engineering	The Australian Pulp and Paper Institute is an educational and research centre within the Department of Chemical Engineering, Monash University, Clayton campus. The Institute is sponsored by the Pulp and Paper Manufacturers Federation of Australia, with funding and student commitments from its member companies. It also receives valuable support from supplier companies.
Centre for Design	RMIT University	Research Expertise & Services Developing and demonstrating new design methods, tools and processes aimed at improving the environmental performance of products and services Working with industry to design environmentally improved products and services, and to develop more strategic environmental directions Advising government agencies on policy and programs to reduce environmental impacts through design Exploring new design concepts and scenarios for a sustainable future Maintaining a national and international network of research and information exchange in 'Design for Environment'
Centre for Electrical Power Engineering	Monash, Faculty of Engineering	Early in 1991, a Centre for Electrical Power Engineering (CEPE) was established at the Clayton Campus of Monash University, Melbourne. Since then the Monash Centre has become widely recognised and respected in many facets of electrical power engineering. The Centre's reputation was built initially on its considerable academic capabilities. Now that reputation has been enhanced by the Centre's ability to turn ideas, theory, research findings, and design concepts into practical solutions for government utilities and private industry. CEPE's work includes power systems analysis; variable speed drives; condition monitoring of electrical plant; high voltage engineering; quality of electrical supply; asset and demand management. Practical solutions are the core of CEPE's mission. The centre has a significant role in the development of Victoria's electrical power system and electrical manufacturing industry.

Research Centre	Host University	Capability overview
Centre for High-Resolution Spectroscopy and Opto-Electronic Technology	Monash University, Faculty of Science	The Centre (CHRSOT), has been established to undertake fundamental and applied research involving molecular spectroscopic techniques and instrumentation, including the development of commercially significant spin-off instrumentation and software products from the research.. In accordance with its aims, CHRSOT operates as a self funded entity (i.e. not drawing on university funding for its activities. This status has been achieved by means of a combination of ARC grants in the areas of theoretical astrophysics, laser spectroscopy and infrared spectroscopy together with substantial R&D contracts with industry.
Centre for Imaging and Applied Optics	Swinburne University of Technology	CIAO is a research centre of the School of Biophysical Sciences and Electrical Engineering (BSEE) at Swinburne University of Technology, Melbourne, Australia. CIAO is part of the Swinburne Optics and Laser Laboratory (SOLL). The Centre commenced operations in January 1998. CIAO and is externally funded by Optiscan Imaging Ltd. and HBH Research P/L. The initial focus of CIAO was in the area of medical and industrial applications of scanning laser microscopy and other spectrally-resolved imaging techniques as well as work on optical fibre sensors. The CIAO has been operating in its new complex for less than a year, however, it has mad a significant contribution to research and development of various Optiscan products.
Centre for Biomedical instrumentation	Swinburne	The Centre for Biomedical Instrumentation was established in 1989 to provide a focus for research and consulting activities related to instrumentation for medical and physiological use. The Centre draws on the strengths in instrumentation and biophysics within the School of Biophysical Sciences and Electrical Engineering. It also works in collaboration with the Swinburne Brain Sciences Institute.
Centre for Materials and Surface Science	Latrobe University, Physical Sciences	The Centre for Material and Surface Science (CMSS) has one of the highest concentrations of research activity and expertise in the area of materials and surface science in Australia. Seven academic staff conduct research programs across the disciplines of physics, chemistry, materials science and electronic engineering. Research activates range from the development of novel scientific instrumentation and fundamentals studies of the electronic structure of semiconductors to the investigation of surface coating technology in the automotive industry and the role of surface chemical properties in charge transport across the surface of packaging polymer films.
Fluid-dynamics Laboratory for Aeronautical and Industrial Research	Monash University	FLAIR actively pursues research in aeronautics and hydrodynamics, tubomachinery, automotive aerodynamics, and mixing enhancement. Much of the work of the Lab is based on fundamental fluid mechanics research. FLAIR is able to provide research across a range of fields, from highly controlled and rigorous strategic scientific research to applied engineering redesigns of fluid processes and related equipment. It also has both experimental and computation expertise of the highest level plus leading software design capabilities. For example, staff at FLAIR have constructed software that has reduced the fuel filling equipment design cycle in the automotive industry dramatically. The staff have experience in a range of industries from automotive and aerospace to mineral processing and manufacturing. Over the past 15 years, they have provided contracted research for many companies including Ford Europe and Australia, Comalco, Western Mining, Warman, Alcoa, and Queensland Alumina Ltd. They have published many articles in leading international journals and conferences and incorporate leading edge experimental, computational and theoretical techniques. The researchers also have strong management skills and experience in leading many successful major research projects with industry.

Research Centre	Host University	Capability overview
Graphic Design Centre	University of Ballarat	The Graphic Design Centre will exist to provide creative and commercially successful graphic design services to clients, through experience-based learning. Benefiting from recent high-technology and multimedia developments, the Centre will contribute professional services initially in the regional market. Multifaceted learning processes, research projects within the University and with its partners, and gaining a critical mass of the region's market share will enable the Centre to achieve eventual national and international prominence.
Industrial Research Institute Swinburne (IRIS)	Swinburne University of Technology	The purpose of IRIS is for creative researchers to provide innovative solutions to enhance the competitiveness of entrepreneurial industries through a range of services including collaborative research, technology diffusion programs, postgraduate courses, and industry training programs. Around 80% of the research carried out at IRIS is in collaboration with industry partners. The remaining 20% of the research performed within the IRIS is very applied in nature and results in industry participation at the conclusion of the initial R&D phase - ie at the commercialisation phase. IRIS receives many ARC Large Grants, SPIRT Grants etc from both State and Federal Governments
Intelligent Robotics Research Centre	Monash University, Faculty of Engineering	The major strengths of the IRRC at an internationally recognised level, are in the following areas: Machine Perception including image processing, ultrasonic sensing, tactile sensing, pattern recognition, computer vision, optical flow, range finding, olfactory sensing and interactive computer graphics Robot Navigation, including localisation, environmental modelling, simultaneous localisation and map building (SLAM), and collision-free path planning. In addition, we have expertise in microcomputer systems, parallel computer architectures, VLSI design, electronics, control systems, communications, expert systems applications, general artificial intelligence and artificial neural networks.
Key Centre for Advanced Materials Technology	Monash University, Faculty of Engineering	The Centre is a resource for industry and offers the following services: Cost effective research and development ▪ Technology audits and materials specification ▪ Independent materials testing and analysis ▪ Materials degredation studies (wear, corrosion, weathering, etc) ▪ Product development ▪ Process troubleshooting ▪ Advice on the 125% R&D tax concession ▪ Authoritative opinion on litigation ▪ Workshops and seminars in emerging technologies In delivering these services, CAMT is able to draw upon the extensive resources of the Departments of Materials Engineering, Chemistry, and Physics at Monash University. CAMT Associates from these departments have expertise in a wide range of materials and related technologies, and are truly independent specialists, having no preferred relationship with any industry or organisation.
Laboratory for Turbulence Research in Aerospace & Combustion (LTRA&C	Monash University	The major role of the LTRA&C is to undertake high quality research in a number of areas which have direct applications to such fields as: aerodynamics, flight dynamics, propulsion, mechanical engineering and heat and mass transfer. The product of this research is published in the most prestigious international peer reviewed journals and international conferences around the world.

Research Centre	Host University	Capability overview
Micro-analytical Research Centre	University of Melbourne, Faculty of Science	MARCO produces a range of products for Nuclear microscopy. These products range from advanced magnetic lenses for focusing fine probes to complete nuclear microprobe systems. The original brief for the Centre was to encourage and promote the use of Nuclear Microscopy in the analysis of materials. MARC has however, grown to encompass many interests in materials science (especially wide band gap semiconductors), and analysis using Raman microscopy and most recently Scanning Probe Microscopy.
Polymer Technology Centre	RMIT University	World Class Polymer Processing Facility with a strong focus in the field of polymers (plastics and rubber), encompassing formulation & development of novel polymers and composites, high level industrial sector collaboration in all polymer related fields and in particular the flexible packaging and food industry. Strong ability to apply research outcomes of both short and long duration to Industry partners requiring medium to long term value adding to their businesses. The Polymer Technology Centre facilities allow the medium scale up of product development in each of the fields of Injection, Blow and Rotational moulding, Extrusion of Film, Sheet, Pipe and Profile cross sections, vacuum thermoforming, compression of thermosetting & thermoplastics polymers and elastomers. Additionally the Centre has a full Rapid Prototyping service utilising the techniques of Stereolithography and Vacuum Casting of polyurethanes, epoxy & polyester resins. The Centre is considered to be a real world interface to plastics & rubber raw material manufacturers, equipment manufacturers, polymer processors and convertors as well as end users of plastics & rubber products. The major strength is the delivery of value adding solutions over a broad base of applications that is unique in Australian Institutions
Rheology and Materials Processing Centre	RMIT University	Enhancement of melt strength of linear low density polyethylene by blending with low density polyethylene to achieve stable blown film extrusion (collaborative project with CRC for Polymers/ORICA) Modelling of thermoforming process for polypropylene and Acrylonitrite-Butadiene-Styrene. The modelling was carried out using the T-Formcad software of Polydynamics, Canada. The extensional rheology data was measured using the Melt Extensional Rheometer constructed at RMIT, (collaborative project with Montell and Polydynamics). Production of rheologically controlled plaster. This project aims to produce gypsum based plaster with selected properties for a wide a or select set of end use conditions through better control of its manufacture. (Collaborative project with Boral Plasterboard).
Vision Metrology Services Unit	Department of Geomatics, faculty of Engineering, University of Melbourne	The unit was established as a joint initiative of the Department of Geomatics at The University of Melbourne and the Advanced Engineering Centre for Manufacturing, and now functions as a stand-alone commercial operation. The VMS Unit offers specialist 3D measurement services to the sectors of large scale manufacturing and engineering surveying. The primary measurement tool used by the VMS is the V-Stars Vision Metrology System from Geodetic Services, Inc.
Sir Lawrence Wackett Centre for Aerospace Design Technology	RMIT University	The Wackett Aerospace Centre is a major participant in the Co-operative Research Centre for Advanced Composite Structures (CRC-ACS) and in the DSTO Centre of Expertise in Aerodynamic Loading (CoE-AL). The Centre focuses its attention on the following fields of research: ▪ Aerospace design and optimisation of aerospace systems. ▪ Advanced fibre composite research and development. ▪ Guidance, dynamics and control design. ▪ Aerodynamic analysis and design.

Research Centre	Host University	Capability overview
		▪ Computational mechanics including finite-element and finite difference methods, computational fluid mechanics and boundary integral equation techniques. ▪ Structural and dynamic testing. ▪ Aircraft loads determination. ▪ Vibration testing and analysis including flutter certification of light aircraft. ▪ Approval for civil aircraft modification and repairs, and aircraft certification. ▪ Crashworthiness analysis, design and evaluation. The Aerospace Design and Commercial Office (ADCO) is a commercial design office providing design and consulting services to the aviation and aerospace industries. The ADCO draws on the wide-ranging experience of its staff and associates, and the resources of the Wackett Aerospace Centre and the Departments of Aerospace Engineering and Mathematics at RMIT. ADCO is recognised by the Civil Aviation Safety Authority as an approved design organisation, authorised under Australian Civil Aviation Regulations for the approval of civil aviation modification and repairs.

6.2 Investment

Victoria allocates a high level of investment to research and development in manufacturing. While there is a substantial level of Commonwealth support, the data do not indicate that the State Government provides any research and development support for this sector.

Table 13: Manufacturing - Research and Development Expenditure 1996-97

Socio economic objective	Commonwealth Government $'000	State Government $'000	Higher Education $'000	Business $'000	Private Non-Profit $'000	Total Expenditure $'000
Processed food products and beverages	4,048.2	0.0	3,704.7	108,846.0	0.0	116,598.9
Fibre processing and textiles; footwear and leather products	26,474.9	0.0	83.7	11,729.0	0.0	38,287.6
Wood, wood products and paper	2,421.8	0.0	813.0	0.0	0.0	3,234.8
Human pharmaceutical products	11,885.1	0.0	1,427.6	51,910.0	1,367.3	66,590.0
Veterinary pharmaceutical products	3,411.7	0.0	878.6	0.0	0.0	4,290.3
Agricultural chemicals	2,284.0	0.0	212.3	5,490.0	0.0	7,986.3
Industrial chemicals and related products	12,826.8	0.0	1,852.3	61,866.0	0.0	76,545.1
Basic metal products (incl. Smelting)	5,905.3	0.0	1,293.7	42,094.0	0.0	49,293.0
Ceramics, glass and industrial mineral products	2,373.6	0.0	423.4	8,432.0	0.0	11,229.0
Fabricated metal products	3,990.1	0.0	1,281.7	53,303.0	0.0	58,574.8
Transport equipment	3,093.0	0.0	3,601.7	235,326.0	0.0	242,020.7
Computer hardware and electronic equipment	0.0	0.0	596.0	0.0	0.0	596.0
Communication equipment	121.6	0.0	1,882.0	113,369.0	0.0	115,372.6
Instrumentation	5,037.7	0.0	1,840.4	22,930.0	0.0	29,808.0
Machinery and equipment	3,984.6	0.0	2,401.1	51,829.0	0.0	58,214.7
Other manufactured products	5,910.0	0.0	523.2	23,378.0	0.0	29,811.2
	93,768.1	0.0	22,815.4	790,502.0	1,367.3	908,452.7
	10.3	0.0	2.5	87.0	0.2	100.0

Commonwealth support for manufacturing is directed through the CSIRO and other programs.

It is of interest that about 30 percent of the business research and development investment in Victoria is in the area of transport equipment, where Victoria is a significant exporter. Fifteen percent is invested in communication equipment and 14 percent is in food processing. Less than seven percent of the research effort is allocated to human pharmaceuticals.

6.3 Capability Indicators

There were 23 organizations that provided survey responses in connection with manufacturing

Table 14: Research Capability in Manufacturing

Fields of Research	No of Capabilities Identified	Total Capability Level	Average Capability	No of FOR classes	Count of Orgs
Agricultural Sciences	1	1	1.0		
Applied Sciences and Technologies	105	358	3.4		
Biological Sciences	16	44	2.8		
Chemical Sciences	41	135	3.3		
General Engineering	21	80	3.8		
Information, Computer and Communication Technologies	47	189	4.0		
Medical and Health Sciences	7	18	2.6		
Physical Sciences	15	54	3.6		
	253	879	3.5	85	23

As can be seen, eight fields of research are identified as capabilities in manufacturing. The highest level of capability is in applied sciences and technologies, chemical sciences and information, computer and communication technologies. This result points to the significance of what are referred to as new and emerging technologies in manufacturing.

6.4 Comments Made In Focus Groups And Consultations

Comments in the focus groups suggested that the capability in manufacturing STI support was highly fragmented. The large number of separate centres would support this view.

The manufacturing sector in Victoria, overall, has been in substantial decline for the past decade, in terms of share of the State domestic product and employment. Manufacturing is generally seen as a sunset/smokestack industry. Whitegoods and TCF manufacture in particular are suffering.

Some of the decline reflects the impact of outsourcing of back-office functions (information technology, accounting, etc) and some research and development functions that may be picked up in other areas.

The creation of a new Victorian Minister for Manufacturing signals a challenge to this decline. A recent initiative aims to encourage schoolchildren into a career in the sector. At a current Motor Show the Department has organised for industry representatives to talk about their careers to school students to raise awareness and stimulate interest.

In contrast to this general decline, however, there are a number of areas where the 'new/smart' manufacturing (characterised by manufacturing-service integration, supply chain management, etc) displays considerable strength. The information in the ABS data and the capability indicators suggest that manufacturing in becoming increasingly "knowledge intensive".

The **automotive sector** is characterised by:

- Strength in manufacturing (Ford & Holden)
- Visibility and effectiveness of the Concept Car I and II scheme (SIRF acknowledged as project manager)
- Strong networking between industry associations, companies and CSIRO, around the concept car; 100 people from across this network are meeting on a monthly basis in a friendly collaborative environment
- Strong leadership – the vision for the concept car came from Garry Millard of Millard Design whose idea was considered 'way out' initially
- Vibrant component industry – Air International, Suspension Components, Autolive, etc
- Research and development infrastructure within companies is strong and supports a comparatively high degree of industrial research
- There is some strength in Public Sector research facilities and capabilities, for example, the Monash University Wind Tunnel, but this was not characteristic.

The **aerospace sector** is characterised by:

- Strong presence of major global aerospace companies Hawker de Havilland, British Aerospace, Astra
- Strong links with public sector research organizations – CSIRO, DSTO
- BAe committed to developing a cell of aerospace engineers at Fisherman's Bend
- The establishment of an Aerospace Centre at Monash University, providing an undergraduate degree that will emphasise computational science that underpins effective IT application
- The attraction of the international industry to Melbourne once every two years for the Avalon Air Show.

6.5 Initiatives Proposed In Focus Groups

Participants at focus groups identified an urgent need for a Directory so that people can identify available infrastructure products and services. An additional benefit will be that it will provide the basis for a more rational approach to instrumentation purchase.

Other suggested initiatives included:

- A micro-manufacture facility could provide a substantial capability to support the further development of new manufacturing
- An instrumentation/testing facility could provide a substantial capability to support the further development of new manufacturing
- Building on/support IRIS feasibility study to involve all the players in technology development for manufacturing – CSIRO, Universities, CRCs, leading companies, to develop a directory of expertise and capability
- Assess the demand and requirements for centralised 'clean room' facilities and operational expertise.

7 Construction

7.1 STI Capability

The major contributor to STI capability is in the CSIRO.

- **CSIRO**

Division/Unit	Location	Research Capability
Building, Construction and Engineering	Highett	Core capabilities include sustainable materials engineering, thermal and fluids engineering, and infrastructure systems engineering. See web page for specific project details The division has three sites: Highett Vic with 182 staff; North Ryde Sydney with 47 staff; and Brisbane with 3 staff. The CBCE contributes strongly to both direct research outcomes with Vic building construction and other sectors through the collaborative projects listed on the Web site as well as information dissemination through conferences, workshops, university collaboration etc. Staff salaries and other expenditure by CSIRO within Victoria are of the order of $18m pa. Core capabilities include sustainable materials engineering, thermal and fluids engineering, and infrastructure systems engineering. See web page for specific project details The division has three sites: Highett Vic with 182 staff; North Ryde Sydney with 47 staff; and Brisbane with 3 staff. The CBCE contributes strongly to both direct research outcomes with Vic building construction and other sectors through the collaborative projects listed on the Web site as well as information dissemination through conferences, workshops, university collaboration etc. Staff salaries and other expenditure by CSIRO within Victoria are of the order of $18m pa.

There are no CRCs or university research centres specifically targeted at construction. As indicated, some of the work in the manufacturing CRCs and Centre would have implications for construction, particularly those concerned with materials. The capability in mathematical modelling is also relevant for construction. This is indicated in the investment section.

7.2 Investment

Information on research and development in the construction sector is provided in Table 15.

Table 15: Construction - Research and Development Expenditure 1996-97

Socio economic objective	Commonwealth Government $'000	State Government $'000	Higher Education $'000	Business $'000	Private Non-Profit $'000	Total Expenditure $'000
Planning	1,769.0	0.0	1,753.6	0.0	28.6	3,551.1
Design	3,592.7	541.6	6,894.5	1,029.0	0.0	12,057.8
Materials performance and processes	6,629.8	388.6	1,407.6	9,967.0	0.0	18,393.0
Construction processes	1,967.4	559.0	2,512.6	2,026.0	0.0	7,065.0
Building management and services	2,887.0	0.0	250.1	0.0	0.0	3,137.1
	16,845.9	1,489.2	12,818.4	13,022.0	28.6	44,204.1
	38.1	3.4	29.0	29.5	0.1	100.0

The data point to a substantial investment by the Commonwealth and industry in materials performances and processes.

7.3 Capability Indicators

Information on research capability in the construction sector is provided below.

Table 16: Research Capability in Construction

SOE	Fields of Research	No of Capabilities Identified	Total Capability Level	Average Capability	No of FOR classes	Count of Orgs
Construction						
	Applied Sciences and Technologies	12	44	3.7		
	Chemical Sciences	6	18	3.0		
	Humanities	2	6	3.0		
	Physical Sciences	4	12	3.0		
		24	80	3.3	14	4

The four organizations that responded identified strengths in applied sciences and technologies applied to the construction industry

8 Transport

8.1 STI Capability

Substantial organisational capabilities for STI exist in Vic Roads and University Centres

- **Vic Roads**

Division	Location	Capability Overview
Corporate Planning	Kew	VicRoads manages both heavily trafficked urban roads and lightly trafficked rural roads. Due to the importance of road transport to the State's rural export based economy, VicRoads has developed expertise in balancing road infrastrucuture needs with the need for low-cost freight transport. Optimisation of the road system involves: improving access; reducing travel costs; and providing safe and efficient condidtions for road users. Distinctive capabilities are held in the following areas: - Strategic road network management - Traffic and road use management - Road safety - Registration and licensing - Business information

- **University Research Centres**

Research Centre	Host University	Capability Overview
Institute of Transport Studies (Monash University Node)	Monash University, Faculty of Engineering	The transport research program in the civil engineering department is conducted by staff from the Monash Transport Group (within Civil Engineering) as well as staff of the Institute of Transport Studies. The transport research program is focused into four program areas: ▪ Transport Technology ▪ Travel Behaviour ▪ Road Safety ▪ Transport and Traffic Engineering The research dealing with intelligent transport systems forms part of the transport technology research area. The current research projects relate to advanced traffic management systems (ATMS) and advanced traveller information systems (ATIS). The transport technology area also includes research on freight. The travel behaviour research is concerned with the analysis, forecasting and influencing travel demand. The latter area is also known as travel demand management or mobility management. A variety of projects are also being undertaken in the areas of road safety and transport/traffic engineering.
Key Centre for Transport Management	Monash	No details
Transport Research Centre	RMIT University	Offers broadly-based research, consultancy services and information databases and techniques for land use and transport planning. Research Expertise & Services ▪ Examples of work and projects

Research Centre	Host University	Capability Overview
		▪ Victorian Activity and Travel Survey (VATS)Database
		▪ GIS-based approach to crash rates
		▪ Sustainable transport futures
		▪ Environmental waste management
		▪ Saleability of residential properties sold at auction
		▪ Cyclical behaviour of the residential real estate market in Melbourne
		▪ Cost-effectiveness of repeat reminders and non-response interviews in travel surveys
		▪ GIS-based optimal zone algorithms
		▪ Review of recent travel surveys
		▪ Forecasting travel demand

8.2 Investment

Victoria has a major commitment to research and development in Transport, as is indicated by the data in Table 17.

Table 17: Transport - Research and Development Expenditure 1996-97

Socio economic objective	Commonwealth Government $'000	State Government $'000	Higher Education $'000	Business $'000	Private Non-Profit $'000	Total Expenditure $'000
Ground transport	3,210.9	1,186.0	4,097.4	19,256.0	0.0	27,750.3
Water transport	1.4	0.0	174.4	0.0	4.8	180.5
Air transport	127.7	0.0	50.4	10,109.0	0.0	10,287.1
Other transport	90.3	0.0	47.6	0.0	0.0	137.8
	3,430.2	1,186.0	4,369.7	29,365.0	4.8	38,355.7
	8.9	3.1	11.4	76.6	0.0	100.0

The research and development investment is concentrated in the ground transport area and occurs predominantly in the business sector.

8.3 Capability Indicators

Information on research capability in the transport socio-economic indicator is provided in Table 18.

Table 18: Capability in Transport

SOE Fields of Research	No of Capabilities Identified	Total Capability Level	Average Capability	No of FOR classes	Count of Orgs
Transport					
General Engineering	12	26	2.2		
Social Sciences	3	6	2.0		
	15	32	2.1	8	5

Respondent organizations did not indicate high levels of capability in research areas applied to transport.

9 Information And Communications

9.1 STI Capability

Victoria has a very extensive STI cooperative and collaborative capability in information and communications

- **CSIRO**

Division/Unit	Location	Capability Overview
High Performance Computing and Communications Centre.	Melbourne	The HPCCC provides facilities for CSIRO and the Bureau nationally. However, the bulk of the Bureau usage comes from its head office staff, who are located in Melbourne, and the bulk of the CSIRO usage comes from CSIRO staff located in the Melbourne suburbs (about 80% of CSIRO's 50% share is used by the users). The HPCCC provides employment for 18 staff, and provides essential research infrastructure for over 200 scientists, most of whom work in the Melbourne region. The HPCCC acts as a source of expertise to other centres (e.g. the APAC regional and peak facilities), and the users form the largest single grouping of computational scientists in the country. There are flow-on effects, e.g. in the basing of NEC's and Cray Research's support services in the Melbourne region, and in the employment of staff to support the scientists. The HPCCC has the biggest public concentration of computing power in the country, and researchers in other organisations who have collaborations with the Bureau or CSIRO can access the facilities
Mathematical and Information Sciences	Clayton, Carlton, Melbourne	Staff in Mathematical and Information Sciences have particular expertise in areas such as: ▪ computer science and engineering ▪ applied mathematics ▪ operations research ▪ statistics and related disciplines.
Telecommunications and Industrial Physics	Clayton	Translating research results into profitable industrial products and processes is a vital part of the division's activities. We serve companies of all sizes across a diversity of industries. Our clients range from large multi-nationals who utilise our specialist skills to fill gaps where they lack expertise to small and medium sized enterprises who turn to us to help develop their core technological strategies and products. Our capabilities in serving commercial clients are well established. We have a depth of business skills including specialist project managers who ensure contracts are professionally executed and completed on time and within budget. We are alert to the commercial sensitivities of our work. Issues such as confidentiality, ownership of technology, conflicts and competitive restrictions are negotiated up front and adhered to on a strict basis. The Division is also responsible for the management of the Deep Space Tidbinbilla Tracking station in Canberra.

▪ Cooperative Research Centres

Centre	Research Expertise
CRC for Enterprise Distributed Systems Technology	Enterprise Modelling. Organisational Policies and Security: Knowledge and Resource Management: Enterprise Processes and Work Practice Support: Component System Engineering:
Australian Photonics CRC	Photonics, optical fibre and planar waveguide materials characterisation, fibre and planar waveguide fabrication and design, optical fibre amplifiers, novel photonic components, photonic integrated circuits, photonic systems and networks, optical fibre sensing technology, advanced waveguide theory, precision manufacturing, network demonstrations and test beds, photonic signal processing, high-speed WDM technologies.
CRC for Sensor Signal and Information Processing	Signal processing, information processing, radar systems, sonar systems, shape inference, artificial neural networks, target tracking, target recognition, data fusion, analytical techniques, array processing.
Australian Telecommunications CRC	Broadband networking architectures, broadband telecommunications access techniques, protocol development and implementation, third generation mobile networks, wideband CDMA, next generation internet, network dimensioning and performance engineering, electronic systems design, application specific chip design, adaptive modulation and coding, wireless system implementation, signal integrity, electromagnetic compatibility.

▪ University Based research Centres

Research Centre	Host University	Capability Overview
Centre for Advanced Technology in Communications (CATT)	RMIT University	Research Services & Expertise ▪ Telecommunications network planning ▪ Teletraffic engineering of communication and computer networks ▪ Network traffic management and traffic measurements ▪ Design of networks for reliability, uncertainty, time zones, performance ▪ Optimal design of Call Centres / Customer queueing systems ▪ Modelling and performance of ATM Networks ▪ Planning and performance of Cellular Mobile networks ▪ Internet Protocol Modelling for performance and routing ▪ Satellite communications
Centre for Astrophysics and Supercomputing	Swinburne University of Technology	The Swinburne Centre for Astrophysics and Supercomputing is hosted by the School of Biophysical Sciences and Electrical Engineering at the Swinburne University of Technology in Melbourne, Australia. The centre is one of the newest and most rapidly growing research centres in Australia. It currently has the largest workstation farm in Australia with 66 Gflops of computational power, and concentrates on problems in astrophysics that benefit from this unique resource. The major projects are precision timing and pulsar searching, both of which are supported by Australian Research Council large grants. We collaborate with several groups around the world but our major

Research Centre	Host University	Capability Overview
		collaborators are at the Australia Telescope National Facility, Caltech, Jodrell Bank and MIT. Our precision timing programme involves use of the FPTM (fast pulsar timing machine) a digital autocorrelator, and CPSR, the Caltech-Parkes-Swinburne baseband Recorder. CPSR is a 20 MHz baseband recorder which uses an Ultra 60 with 4 9GB disk drives and 4 DLT 7000 tape drives. These instruments allow us to make very high time resolution of pulsars (down to 50 nanoseconds). The search project involves a baseband search for sub-millisecond pulsars. We are scanning over the region |b|<20 with 20 MHz of bandwidth. The baseband system allows us to synthesize a 1024 channel filterbank with 20 kHz filters. This largely eliminates dispersing measure smearing. The data takes 160 times real time to process on a DEC 500 MHz workstation. Fortunately we have 16 of them so we can afford to observe for about 10% of the time and still keep up with the data rate. We are also involved in studies of individual pulses from millisecond pulsars and calculations of the implications of pulsar velocities.
Centre for Computational Mathematics	Monash University, Faculty of Science	TBI
Centre for Convergent Technologies	Swinburne University of Technology	CCT is a research centre within Swinburne University of Technology's School of Biophysical Science and Electrical Engineering. Research focuses on the convergence of telecommunications and computing, best exemplified by the Internet. This covers Internet Protocol Internetworking, the underlying broadband and mobile digital telecommunication and data networks, the component multimedia information presentation and communication techniques, the inherent internet software technologies - and the application of all of these technologies to readily accessible uses in our society.
Centre for Geographic Systems and Modelling	Melbourne	The Centre is a joint initiative of the Faculty of Engineering (Department of Geomatics) and the Faculty of Architecture, Building and Planning at The University of Melbourne. The Centre has been established to carry out research on geographic information systems, their applications, environmental visualisation and modelling, and to provide a focus for University teaching in these areas.
Centre for International Research on Communication and Information Technologies (CIRCIT)	RMIT University	CIRCIT is an interdisciplinary research centre within RMIT examining the implications of communication and information technologies and emerging services for the economy and society. Established in 1989 and joining RMIT in 1998, the aim of the centre is to create new knowledge that is relevant to the community, industry and government so as to increase the social and economic wellbeing of people globally. CIRCIT has a well-developed network with information and communication communities in Australia, Europe, the United States, Canada and South East Asia. CIRCIT provides a multi-disciplinary and user-centred approach to issues in the development of information and communication services. Our focus on users and usage, and the design bridge to technology and service developments, has been a major distinguishing characteristic over the last five years. We have also developed the capacity to engage a wide range of stakeholders- industry, government, business, and consumer organisations, and researchers- in the examination of key policy issues through annual Policy Forums and other activities.
Centre for Telecommunications	Monash University,	The Centre for Telecommunications and Information Engineering is a research and development Centre based at Monash University in

Research Centre	Host University	Capability Overview
and Information Engineering	Faculty of Engineering	Melbourne, Australia. The Centre is comprised of two research groups and a number of related Development projects. ANSPAG was formed through the Cooperative Research Centres initiative and commenced its operations in 1994. The group has established a very significant $2million Network Testbed which is used extensively both by ANSPAG researchers and by industry developers.
Centre for Electronic Commerce	Ballarat	Electronic Commerce has been established as a strategic focus area for the University of Ballarat. The University has established the Centre for Electronic Commerce and its Applications (CECA) The Centre is a partnership between Information Services Branch, Information Technology & Mathematical Sciences, the School of Business, SMB Business Cluster and the Office of the Vice Chancellor. The Centre will contribute to academic programs and research in EC and manage current Electronic Commerce Ballarat Projects. The Centre for Electronic Commerce (CECA) is a member of a consortium of 20 Universities involved in research and development of electronic commerce.
Centre for Intelligent Systems	Swinburne	The Center for Intelligent Systems and Complex Processes has been established within the School of Biophysical Sciences and Electrical Engineering (BSEE) to act as a focus for, and to promote, the work being carried out in the school on areas such as artificial neural networks, fuzzy logic, expert systems and genetic algorithms.
Centre for Rural & Regional Information	Ballarat	The Centre for Rural & Regional Information is an initiator and broker of multimedia information services research, development and technology transfer; for the needs and opportunities of rural and regional Victoria with a particular emphasis on new and integrated geospatial information services. The Centre links with schools and research centres at the University of Ballarat, the private sector IT producers, government and information using business.
Department of Computer Science and Computer Engineering	Latrobe	The Department of Computer Science and Computer engineering has an excellent record in software engineering, network engineering, intelligent systems, data engineering, multimedia and visual interaction engineering It also has well established research laboratories with highly qualified, experience team leaders and a track record of successful industry and public sector collaboration. The Department trains high-quality graduates able to take a leading position in IT development. The Department's major contributions to Victorian STI infrastructure include: ▪ Production of IT high quality IT graduates able to take a leading position in the application and development of the latest IT hardware and software; ▪ Provision of training for non-IT graduates seeking to enter the IT industry; ▪ Research training and knowledge generation of direct value to industry; and ▪ Access to highly qualified research personnel, research equipment and space.
Intelligent Robotics Research Centre	Monash	The Intelligent Robotics Research Centre (IRRC) resides within the Computer Systems Engineering group of the Department of Electrical and Computer Systems Engineering of Monash University. The major strengths of the IRRC at an internationally recognised level, are in the following areas: Machine Perception including image processing, ultrasonic sensing, tactile sensing, pattern recognition, computer vision, optical flow,

Research Centre	Host University	Capability Overview
		range finding, olfactory sensing and interactive computer graphics Robot Navigation, including localisation, environmental modelling, simultaneous localisation and map building (SLAM), and collision-free path planning.
Key Centre for Knowledge Based Systems	University of Melbourne Faculty of Engineering	The Key Centre for Knowledge Based Systems was established in 1989 under funding from the Australian Research Council. The University of Melbourne and the Royal Melbourne Institute of Technology (RMIT) jointly support the Centre. The Key Centre for Knowledge Based Systems has built an international reputation as a leading research centre within the following areas: ▪ Multimedia database systems ▪ Information retrieval ▪ Document management systems ▪ Intelligent databases ▪ Logic programming ▪ Constraint programming ▪ Distributed systems
Multimedia Development Unit	Ballarat	The Multimedia Development Unit (MDU) aims to develop the knowledge and use of interactive multimedia at the University of Ballarat and within the region. The Unit is interested in the concept of user engagement with multimedia, in particular multimedia learning materials. The Unit has close links with several national and US multimedia/games development organisations as well as with researchers at several Australian Universities.
Pearcey Centre for Computing	Monash University, Faculty of Information Technology	The Pearcey Centre for Computing is the commercial arm of Monash University's Faculty of Information Technology, the largest Information Technology Faculty in Australia. The Faculty has approximately 200 academic staff. Many are recognised internationally as leaders in areas of IT research and/or teaching. The Centre provides a mechanism for this expertise to be made available to organisations, IT professionals and others interested in furthering their knowledge of the latest developments in IT. We are committed to providing state-of-the-art professional-level IT education and training programs to industry, government and commerce. The courses cover a wide range of areas including programming languages such as C, C++, Visual Basic and Java, the Internet and World Wide Web, database, data communications and network technology, risk analysis and data mining.
Research Centre for Intelligent Tele Imaging	University of Ballarat	The Research Centre for Intelligent Tele-Imaging (RCITI) was established in 1995 at the University of Ballarat. The Centre undertakes research relating to the organisation, access and remote usage of large amounts of text and image data, with an emphasis on finding efficient, effective integrated solutions to specific applications. RCITI research skills cover image analysis, image compression, computer graphics, multimedia, user-interfaces, knowledge-based systems and artificial intelligence. The Centre offers industry and other organisations the opportunity to collaborate in research & development, and consultative projects.
RMIT Multimedia Database Systems ·Software Engineering	RMIT University RMIT University	Technologies and software products providing web based document management solutions for managing corporate information. Examples of work and projects

Research Centre	Host University	Capability Overview
Research Centre	RMIT University	▪ EnAct system for the drafting and access to legislation for the State Government of Tasmania (see www.thelaw.tas.gov.au) ▪ ATO Assist for public access to information provided by the Australian Tax Office ▪ Macquarie Dictionary, providing reference material for school children (see www.dict.mq.edu.au)
Special Research Centre On Quantum Computer Technology - Melbourne Node		The centre is a collaboration between the University of Melbourne, the University of New South Wales and the University of Queensland. The Centre has as it central aim the construction of a quantum computer based on silicon.
Software Engineering Research Centre	RMIT	The Software Engineering Research Centre is an Ericsson funded research group based at The Royal Melbourne Institute of Technology, specialising in Software Engineering and Performance Analysis. SERC undertakes applied research and development for Ericsson, with projects sourced from both within Australia and overseas. SERC staff members also teach and provide supervision for postgraduate students at RMIT.
Swinburne Computer Human Interaction Laboratory	Swinburne University of Technology	The Swinburne Computer-Human Interaction Laboratory (SCHIL) is a research centre at Swinburne University of Technology that focuses on human-computer interaction (HCI) and cognitive engineering. SCHIL is housed within Swinburne University's respected School of Information Technology. SCHIL has earned a reputation for research and professional leadership in the area of HCI since it was formed in 1990. In 1996 SCHIL was recognised as a major research centre within Swinburne and Australia's first full professorial chair in the area of HCI was created. SCHIL opened a new usability laboratory and research facility in 1999 to accommodate its growth.

Whilst the classifications may not be strictly correct, the organizational capability indicates a very high level of access in STI resources in Victoria. This is confirmed by reference to the detailed information in Volume 2.

9.2 Investment

The information and communications sector is a high priority for development by the Victorian Government. Research and development investment is set out in Table 19.

Table 19: Information and communications - Research and Development Expenditure 1996-97

Socio economic objective	Commonwealth Government $'000	State Government $'000	Higher Education $'000	Business $'000	Private Non-Profit $'000	Total Expenditure $'000
Computer software and services	3,027.9	152.6	5,814.1	82,052.0	41.8	91,088.5
Other information services	201.7	405.3	935.9	2,241.0	19.0	3,802.9
Communication services	157.4	180.5	4,041.4	94,932.0	0.0	99,311.3
	3,387.0	738.4	10,791.5	179,225.0	60.8	194,202.7
	1.7	0.4	5.6	92.3	0.0	100.0

The data indicate a very large research and development investment in the business sector.

9.3 Capability

Indicators of research capability in Information and Communications is set out in Table 20.

Table 20: Research Capability in Information and Communications

Fields of Research	No of Capabilities Identified	Total Capability Level	Average Capability	No of FOR classes	Count of Orgs
Information and Communication Services					
Agricultural Sciences	1	3	3.0		
Applied Sciences and Technologies	1	4	4.0		
Biological Sciences	11	36	3.3		
Information, Computer and Communication Technologies	38	145	3.8		
Mathematical Sciences	1	4	4.0		
Social Sciences	3	8	2.7		
	107	389	3.6	28	8

As would be expected, capabilities are concentrated in the information, computer and communication research fields.

9.4 Comments And Issues Raised During Focus Group Meetings And Consultations

There is a considerable asset in the high performance computing centre capacity of the Bureau of Meteorology /CSIRO joint facility, which is dedicated to the staff of the two organizations. CSIRO is aware that the facility has wider industry application, and is extensively used, but it has not been marketed.

The capacity for simulation/modelling capacity has wide application for commercial users.

New enabling technologies, at all scales, have applications across a range of industries, for example, oxygen sensors to blood measurements, automotive combustion and aerospace; hence the need to promote technology development and application associations as much as industry associations.

A number of initiatives were suggested during the review process.

- Pursue effective involvement in APAC
- Support/encourage the investment in the development of specialist computational science expertise.

10 Commercial services

This sector covers a range of service sectors, including wholesaling and retailing. There are not any STI organizations specifically targeting this area.

10.1 Investment

Information in levels of research and development investment are provided in Table 21.

Table 21: Commercial Services - Research and Development Expenditure 1996-97

Socio economic objective	Commonwealth Government $'000	State Government $'000	Higher Education $'000	Business $'000	Private Non-Profit $'000	Total Expenditure $'000
Electricity, gas and water services and utilities	616.8	386.3	458.9	3,301.0	4.8	4,767.7
Waste management and recycling	0.0	0.0	1,183.7	0.0	6.8	1,190.5
Wholesale and retail trade	0.0	0.0	35.9	1,209.0	0.0	1,244.9
Finance, property and business services	45.6	88.0	1,401.8	13,608.0	190.3	15,333.7
Other commercial services	29.6	0.0	460.7	0.0	0.0	490.3
	692.0	474.3	3,541.0	18,118.0	201.8	21,782.2
	3.2	2.2	16.3	83.2	0.9	100.0

The major areas of investment are in finance, property and business services by the private sector.

10.2 Capability

Information concerning research capability in the commercial services sector is provided in Table 22.

Table 22: Research Capability in Commercial Services

SOE Fields of Research	No of Capabilities Identified	Total Capability Level	Average Capability	No of FOR classes	Count of Orgs
Commercial Services					
Agricultural Sciences	4	14	3.5		
Biological Sciences	5	14	2.8		
Chemical Sciences	9	34	3.8		
Earth Sciences	2	6	3.0		
40599 Hydrology	1	2	2.0		
General Engineering	2	5	2.5		
Information, Computer and Communication Technologies	28	106	3.8		
	52	185	3.6	25	6

It is apparent that the research effort, and capability is in the area of information, computer and communications technologies. It points to the high end use of this area of these technologies.

11 Health and Medical Services

11.1 STI Capability

Victoria has a large number of Health and Medical Research Institutes and Centres. Several initiates have been created by legislation, but the vast majority operate within Hospitals and University Medical Faculties.

- **Hospital Based, Government and Independent Medical Research Institutes**

Seen as the "Flagship" and most visible example of Commonwealth support for Medical Research. Grants are allocated to six institutes, four of which are in Melbourne. The institutes are recognised internationally for their contribution to research

Centre	Location	Capability Overview
Arthritis Foundation of Victoria Centre for Rheumatic Diseases	Parkville	The AFV Centre is a joint venture between the Arthritis Foundation of Victoria, the Royal Melbourne Hospital and the University of Melbourne. Each of the partners recognise the increasing importance of rheumatic diseases and each has expertise to bring to support the Centre. The Centre has a broad agenda of promoting patient care, education and research in rheumatic diseases in Victoria. The Centre has strong links with the Rheumatology Unit of the Royal Melbourne Hospital (one of the largest in Australia), the University of Melbourne Department of Medicine, the Victorian Branch of the Australian Rheumatology Association, the Reid Rheumatology Laboratory at the Walter & Eliza Hall Institute, clinical departments of the North Western Heath Care Network and the North Western Division of General Practice.
Austin Research Institute	Heidelberg	The Austin Research Institute has a world recognised team of 100 researchers dedicated to combating cancer and finding ways to treat many common diseases by using the most recent advances in genetic engineering and immunology.
Austin and Repatriation Medical Centre		TBI
Austin Hospital Medical Research Foundation		TBI
Australian Genome Research Facility	Parkville	The Australian Genome Research Facility (AGRF) was established as part of the Commonwealth Government's Major National Research Facility (MNRF) Program. It has received a one off grant of $10 million for the purchase of equipment. The AGRF is hosted by the University of Queensland and The Walter and Eliza Hall Institute of Medical Research. The AGRF is an efficient state-of-the-art facility for the collection of molecular genetic information, covering large-scale DNA sequencing, genotyping services and other resources for the genetic and physical mapping of chromosomes, mutation detection and associated bioinformatics.
Baker Medical Research Institute	Melbourne	The Baker is an NHMRC block-funded Institute, affiliated with Monash University and the Alfred Hospital. The Victorian Government and the Baker Benefaction also support the Instiute. It is also a WHO collaborating centre for research and training in cardiovascular diseases, the only one in Australia.

Centre	Location	Capability Overview
		The Institute aims to increase the understanding of the underlying causes of hypertension and atherosclerosis, to use this knowledge to prevent heart and vascular disease in the community and improve medical and surgical treatment
Bernard O'Brien Institute of Microsurgery	Fitzroy	The Bernard O'Brien Institute of Microsurgery, based at St Vincent's Hospital is a surgical research centre with general surgical interests, but with a special focus on reconstructive plastic surgery and in particular, the management of soft tissue and limb trauma.
		It undertakes clinical and experimental research in the field of reconstructive surgery and especially microsurgery for the betterment of the health of those afflicted by injury, disease or abnormality.
Bionic Ear Instiute	East Melbourne	The Australian Bionic Ear & Hearing Research Institute was established in 1984, out of the continuing need to provide additional research funds to support the further development of the Bionic Ear, pioneered in the Department of Otolaryngology, at the University of Melbourne from 1970-1979
		The BEI contributes directly to Victoria's Science, Technology and Innovation infrastructure by research outcomes, i.e. the Bionic Ear, which has been implanted into 25 000 people worldwide and indirectly, through research training via its association with the University of Melbourne Department of Otolaryngology.
Bimolecular Research Institute	Parkville	The Bimolecular Research Institute (BRI) was established in 1990 as a joint initiative between the CSIRO and the Strategic Industry Research Foundation (SIRF) to be a centre of expertise for structure-based drug design.
		BRI complements and extends the research capabilities of this area. Ten million dollars have been invested in sophisticated scientific equipment, including high-field NMR spectrometers, X-ray detectors and specialised computers
Centre For Behavioural Research In Cancer	Carlton	The Centre for Behavioural Research in Cancer (CBRC) was set up in 1986 by the Anti-Cancer Council of Victoria to conduct research into behavioural aspects of cancer prevention, detection and rehabilitation.
		CBRC has programs of research that contribute to knowledge of the behavioural aspects of cancer control, particularly primary and secondary prevention and increasingly in tertiary prevention. In particular, the focus of the program is on providing a research base to underpin the Anti-Cancer Council of Victoria's overall responsibilities to advise on and implement cancer control at a population level in Victoria.
Centre for Developmental Cancer Therapeutics	Parkville	The CDCT is a consortium which brings together several Melbourne institutions with international reputations for first class cancer research and treatment. The philosophy of the consortium is to conduct clinical studies which are focussed in areas where there is local expertise and experience.
		The close geographic proximity of the CDCT's participating institutions has enabled many productive collaborations to take place. As a result, the consortium has the facilities and experience required for conducting Phase I and II trials. It has an established record of conducting clinical studies which meet internationally accepted standards. There is particular expertise with biological response modifiers, especially the hemopoietic growth factors.
The Centre for Early Human Development/Animal Gene Storage and Resource Centre of Australia	Clayton	The platform technology which underlies most of the Centre's work is that of assisted reproduction; fertilisation and embryo development in the laboratory. The technique of in vitro fertilisation was pioneered and applied to human infertility and animal production by Professor Trouson and his colleagues.
		The Centre continues to be a world leader in the area of assisted reproduction, but importantly the strength of this platform technology has enabled the group to move into the leading edge of two new technologies which will have a revolutionary impact on the future of medicine and

Centre	Location	Capability Overview
		biotechnology, human embryonic stem cell biology and animal cloning.
Howard Florey Institute of Experimental Physiology and Medicine	Parkville	The work of the Institute began in 1947ino the functions of the kidney. Subsequently, the Institute decided to investigate factors which control salt and water balance in health and disease. In January 1997, the Institute entered new era, with a major focus on the brain, and new scientific groups have been recruited.
Heart Research Centre	Carlton South	The Heart Research Centre was established in 1989 to undertake behavioural, psychological and social research. Findings are used to guide the development and testing of methods to improve the quality of life of patients, families and communities and to encourage healthy behaviours, which should reduce premature disability and death from CVD. Several of the Centre's studies concern secondary prevention of CVD and cardiac rehabilitation. Studies have clearly demonstrated that by modifying the risk factors of those with established disease, CVD mortality and morbidity can be significantly decreased and health care costs reduced. Primary prevention is also being addressed in studies of high risk groups, including families of cardiac patients, rural dwellers and manual workers.
Institute for Drug Technologies	Boronia	IDT is a publicly listed pharmaceutical development and manufacturing company that focuses on the following: ▪ Manufacture of active pharmaceutical ingredients to international standards of GMP ▪ New drug development and scale-up ▪ Clinical research ▪ GMP project management and consulting.
Institute for Reproduction and Development	Clayton	IRD comprises ten research groups led by internationally recognised scientists, conducting medical and biological research into the life sciences of reproduction and growth. The Institute is a designated World Health Organisation collaborating centre for research in human reproduction The Institute of Reproduction and Development is committed to excellence in the performance of medical and biological research in the life sciences of reproduction and growth. The Institute will employ its research knowledge to enhance the education of students, the professional advancement of medical practitioners and scientists, and the community's understanding of these life sciences. The Institute will promote the application of its research to benefit the reproductive health of women and men, the growth and development of babies and children, the development of Australia's agricultural industry, and the preservation of the world's endangered species.
Ludwig Institute for Cancer Research	Parkville	The Ludwig Institute for Cancer Research is a worldwide network of ten branches in seven countries dedicated to basic and clinical cancer research. The branch in Melbourne was established in 1980 in collaboration with the Royal Melbourne Hospital , the University of Melbourne and the Walter and Eliza Hall Institute. In 1990 an additional campus was established at the Austin & Repatriation Medical Centre creating a major site for the Institute's clinical programme
Macfarlane Burnett Centre for Medical Research	Fairfield	The main research interest of the Macfarlane Burnet Centre is viruses. The Centre's work ranges from basic laboratory research on viruses such as HIV and hepatitis, through to the design, evaluation and implementation of public health programs to prevent the spread of these viruses. You can learn more about what we do at this web site. Although the Centre is located in Melbourne, Australia, we are active overseas especially in the Asia Pacific region, and currently have field

Centre	Location	Capability Overview
		offices in Indonesia, Vietnam, Nepal and Switzerland. The field offices are managed primarily through the International Health Unit and the Epidemiology & Social Research Unit of the Centre. The Centre is currently also the administrative home of the Australian National Centre for HIV Virology Research, which is a network of 9 laboratories in 5 Australian capital cities, all working on basic aspects of HIV virology.
Mental Health Research Institute of Victoria	Parkville	In 1987 the Mental Health Research Institute was incorporated in Victoria and became a fully independent research organisation with a focus on neurosciences.. Research affiliations include the University of Melbourne, Monash University and Royal Melbourne Hospital. The Mental Health Research Institute is a fully independent research institute, and the largest and most productive of its type in Australia. The research program spans neuropathy and neurochemistry, clinical neuropsychiatry amd statistical and policy analysis. The ultimate goal of the Institute's work is to increase scientific knowledge in order to improve diagnostic, therapeutic and preventative measures in mental illnesses. Over the last decade the Institute has played a significant role in research worldwide on both schizophrenia, a debilitating disease in a large number of young people, and Allzheimers disease, the prevalence of which will increase substantially over the next decade because of the ageing of the population
Murdoch Institute for Research into Birth Defects	Parkville	The MCRI was formed when The Murdoch Institute and the Royal Children's Hospital Research Institute, merged in January 2000, creating the largest children's health research institute in Australia, with over 300 staff. The merger brought together international experts in human genetics and genomics, paediatrics and neonatology, clinical trials and public health, education and ethics.
Mutation Research Centre	Fitzroy	The Mutation Research Centre was formed to provide an international focus for the speciality of human genetics involved with mutation: its measurement, documentation, effect, therapy and possible prevention. It commenced operations in January 1996 at the St Vincent's Hospital campus in Melbourne. The group leaders are responsible for their own funding and (as an overall research unit) are encouraged to reach their full potential. This is in contrast to many Australian research centres
National Aging Research Institute	Parkville	The National Ageing Research Institute is Australia's foremost centre of research into the causes and consequences of ageing and its social accompaniments. Research is spread over four areas: All aspects of the biology of ageing, including the cause, prevention and cure of disease, and the relief of suffering associated with ageing; The provision of clinical care, health sciences, and aged-care technologies; The health status, health needs and social requirements of the aged. The Institute aims to develop the highest standards of study and practice in medicine as it relates to the aged. Further, it aims to promote education concerning ageing by the expansion, advancement, and dissemination of knowledge concerning all aspects of ageing.
Parkville Bioinformatics Consortium	Parkville	The Parkville Bioinformatics Consortium is the product of a cooperative agreement between the Ludwig Institute for Cancer Research (Melbourne Branch), The Walter and Eliza Hall Institute of Medical Research and the CSIRO Division of Molecular Science (Parkville Laboratory).
Peter MacCallum Cancer Institute	Melbourne	Peter MacCallum Cancer Institute is a comprehensive specialist oncology centre providing cancer services at the central site in Melbourne and through external clinics and satellites throughout Victoria.
Prince Henry's Institute of	Clayton	The Institute undertakes research in the following areas:

Centre	Location	Capability Overview
Medical Research		▪ Breast Cancer ▪ Endocrine Cell Biology ▪ Endocrine Genetics ▪ Female Reproductive Endocrinology ▪ Male Reproductive Endocrinology ▪ Menopausal Medicine & Ovarian Cancer ▪ Neuro endocrinology ▪ Uterine Biology
Royal Children's Hospital Research Institute	Parkville	Established in 1960, the Research Institute is an independent research organization, operating as a company limited by guarantee, governed by its own Board of Directors. The Institute provides a focus for research at the Royal Children's Hospital in Melbourne. It aims to improve the health of children and adolescents by promoting, supporting and undertaking research.
St Vincent's Institute of Medical Research	Fitzroy	The Institute is an independent Medical Research Institute with its own Board. It is situated on the campus of St. Vincent's Hospital, and is associated with that body as well as with the University of Melbourne. A number of the scientific staff have Honorary Academic appointments with the University of Melbourne and supervise graduate students of that University. The Institute is distinctive for its studies of protein structure and function and the contributions of this to cell biology especially in cancer and bone. It is the only medical research Institute in Australia with a protein crystallography unit, and has units for the study of bone cell biology and of the properties of the protein kinase class of enzymes that are among the top few in the world. The Institute is the host institution for the National Serological Reference Laboratories, whose role is quality assurance of test kits for the diagnosis of communicable diseases.
Victorian Breast cancer Consortium	Carlton	The Consortium involves: ▪ The Walter and Eliza Hall Institute of Medical Research ▪ Prince Henry's Institute of Medical Research ▪ Austin Research Institute ▪ Baker Medical Research Institute ▪ St. Vincent's Institute of Medical Research ▪ Peter MacCallum Cancer Institute
Victorian Breast cancer Initiative	Parkville	The VBCRC is a consortium of medical research institutes forming an institution without walls, and including a number of Melbourne's leading research organizations.
Walter & Eliza Hall Institute of Medical Reserach	Parkville	The Walter and Eliza Hall Institute of Medical Research is Australia's foremost biomedical research institute. Its great traditions of excellence, honed over an eighty year history, have secured an outstanding international reputation. Fundamental discoveries have been translated into the clinic and give substantial stimulus to Australia's biotechnology industry. The Institute's high level of achievement has attracted many prestigious international awards and honours, including the 1960 Nobel Prize for Medicine to Sir Macfarlane Burnet. Currently five of its staff are Fellows of the Royal Society and seven are Fellows of the Australian Academy of Science. The major research themes are: the development of blood cells and their malignancies; the leukemias and lymphomas; the immune system and autoimmune disease such as diabetes and rheumatoid arthritis; control of

Centre	Location	Capability Overview
		parasites, particularly malaria; early mammalian development, especially of muscle and the nervous system. Increased attention is being directed to genetic predisposition to disease, with the Institute positioning itself to take full advantage of the Human Genome Project, an international endeavour cataloguing the entire library of mammalian genes

Information from other sources indicates that there are many centres within Universities engaged in health and medical research.

- **CSIRO**

Division/Unit	Location	Research Capability
Health and Nutrition	Parkville	As a centre of excellence in health and medical research, we focus our research programs on the improvement of human well-being and community health, whilst enhancing the competitiveness of the Australian food, pharmaceutical and food-related pharmaceutical industries. The outcomes of our research address current and emerging healthcare challenges and are realised through prevention of disease, treatments and diagnosis. CSIRO Health Sciences and Nutrition offers both laboratory and clinic-based facilities. Its commitment to health-related research supports a range of technologies including structure-based drug design, molecular and cellular biology, nutrition, pharmaceutical chemistry, diagnostics, pharmacology, physiology and consumer science; it also supports involvement in three Cooperative Research Centres and the Biomolecular Research Institute.

- **Health And Medical Research Centres Linked to Victorian Universities**

Research Centre	University	Capability Overview
Accident Research Centre	Monash	TBI
Australian Research Centre in Sex, Health and Society	Latrobe	Research is undertaken in the following fields ▪ Clinical sciences, ▪ Public health research, ▪ Health services research, ▪ Political sciences and public policy, ▪ Sociology, ▪ Anthropology, ▪ Social studies, ▪ Human geography

Research Centre	University	Capability Overview
Brain Sciences Institute	Swinburne	The research mission of the Brain Sciences Institute is to understand the relationship between cognitive processes and affective states, and the rhythms of electrical activity in the human brain. This mission is carried out with a research strategy that is multidisciplinary and across four research streams. These are Basic Neuroscience, Cognitive Neuroscience, Clinical Neuroscience and Neuroscience Instrumentation. These streams are interrelated and are all part of a focussed research strategy which allows for a wide range of research projects. An important feature of any project in the Cognitive and Clinical Neuroscience streams is the use of functional brain imaging methods including brain electrical activity mapping based on Steady State Probe Topography, Positron Emission Tomography and Functional Magnetic Resonance Imaging.
Cell and Organism Bio-Engineering	Deakin	The Cell and Organism Bio-Engineering Group addresses such problems in three main areas by one research centre and two research sub-divisions. Research in the Centre for Cellular and Molecular Biology at the Melbourne Campus is focusing primarily on determining the effects of heavy metals on biological systems. At the Geelong Waurn Ponds Campus, one sub-division is probing the molecular and cellular mechanisms underlying the responses of plants to environmental stresses such as ultraviolet radiation and attack by patheogenic organisms. The second sub-division, also located at the Waurn Ponds Campus is deciphering the molecular and biochemical control of cellular and systems homestatis in animals. In addition, we provide advanced research traing in these areas at the Honors, Post-Graduate and Post-Doctoral levels.
Centre for Ambulance and Paramedic Studies	Monash	The initial objective is to develop the Centre as a comprehensive, integrated and effective centre of research, education and learning, professional development, and community service, for the benefit of its students, the industry and the community. The vision is to be recognised as a national and international Centre of Excellence in ambulance paramedic education and research. The core business of MUCAPS will be the provision of education and training services to met the needs of Ambulance Service Victoria and providers of private patient transport services. A feature of the new Centre is the mandate to develop a research program in pre-hospital care. It will continue to run a Public Education Unit that will be expanded as a Professional Development unit and will continue to contribute to the teaching of first aid within the faculty of medicine.
Centre for Rural Health (Latrobe Regional Hospital)	Monash	The Centre consists of three streams: Education - The Centre provides graduates with the understanding, skills and values that enable them to contribute to the highest standard of health and care of rural populations. Research - The goal of the Research Stream is to promote, support and conduct research and development which informs rural health policy, education and programs Organisational Process - The goal of the Organisational Process Stream is to develop and implement organisational processes based on co-operation between, and valuing of, all staff in an environment which is open, dynamic and supportive of personal and professional aspirations.
Centre for the Study of Mothers' and Children's Health	Latrobe	Research is undertaken in the following felds ▪ Clinical sciences, ▪ Public health research, ▪ Health services research, ▪ Genetics, molecular biology and biotechnology, ▪ Physiology

Research Centre	University	Capability Overview
Human Communications Research Centre	Melbourne	The original aim of the Human Communication Research Centre (HCRC) was to consolidate the speech processing, psychophysical and biological research carried out in the Department of Otolaryngology which had led to the development of the cochlear implant (Bionic Ear) and the electrotactile aid ('Tickle TalkerTM'). The HCRC would also undertake research that could lead to other devices and sensory aids that could be developed commercially to help deaf people. The HCRC was initially conceived to have direct links with a '[product] development centre' which would develop in collaboration with Australian industry advanced devices to aid the hearing impaired. This vision was fulfilled in 1992 when the Co-operative Research Centre for Cochlear Implant, Speech and Hearing Research (the CRC) was established. Both Centres are based primarily in the East Melbourne Hearing Research Precinct, a research node of world standard. The HCRC concentrates on basic research with the aim of feeding the knowledge gained to the more applied research undertaken through the CRC, leading to final commercialisation. For example, research leading to devices, including the Combionic Aid, the Tickle TalkerTM, and the Speech Processing Hearing Aid, originally carried out in the HCRC, are now being further developed and commercialised through the CRC.
Institute of Public Health Research	Monash	The Southern Health Care Network and Monash University established the Monash Institute of Public Health and Health Services Research in 1998 with the view to develop it into a world-class facility drawing on the collective expertise of the Network, the University, other research institutes with relevant activities, general practitioners and the community as significant participants. The Institute's focus is on creating excellence in health systems. It conducts research in four main areas: ▪ Health Intelligence and Technology Assessment ▪ Lifestyle and Prevention ▪ Quality of Care ▪ Integrated Care Systems
Key Centre for Women's Health in Society	Melbourne	The Key Centre for Women's Health in Society is a teaching and research centre committed to improving women's health by integrating knowledge from social sciences, humanities and medical science. Currently, the Centre is one of five centres worldwide designated to provide training on gender and reproductive health as part of the WHO initiative Operationalizing Cairo and Beijing, and in this context provides short course training for middle level and senior managers in government institutions, inter-government and non-government agencies. The Centre has a strong interdisciplinary profile, with staff from backgrounds including medical anthropology, medical sociology, psychology, feminist economics and medicine. The Centre offers coursework graduate diploma and masters level training in women's health, provides research training at masters, doctoral and postdoctoral levels and participates in medical training. It also provides short courses in women's health which emphasise research methodology and policy and program development.
Lincoln Gerontology Centre for Education and Research	Latrobe	The Lincoln Gerontology Centre (LGC) is a consultancy, research and educational Centre which aims to promote a multidisciplinary understanding of the health, well-being and care of older people. The Centre conducts research and consultancies in the areas of aged care service evaluation and development and social gerontology including health status, health promotion, housing and employment for older people. Funding for the Lincoln Gerontology Centre is derived solely

Research Centre	University	Capability Overview
		from consultancies, research grants, and contract projects.
Rural Health Resource Centre	Ballarat	The Rural Health Resource Centre was established in 1998 to promote excellence in rural health education and delivery in the Central Highlands / Wimmera Region of Victoria. It provides a framework for the collaboration of university, government and community groups. Participating University Schools include Human Movement & Sport Sciences, Behavioural & Social Sciences & Humanities, Nursing, Engineering (VIOSH), and Education. It is in the process of becoming part of the Universities Rural Health Consortium - a national initiative to promote the role of universities in advancing community health.
Victorian College of Pharmacy	Monash	The Victorian College of Pharmacology was amalgamated with Monash University in the early 1990s after a long history of independent operation as a training institution for pharmacy professionals and research academics. Although the College is now nominally a faculty of Monash University, it retains much of its original independence, defering to Monash on only a few select organizational and academic issues. Beneath the College umbrella there are three departments operating with the assistance of unified administrative support. These include: the Department of Medicinal Chemistry, the Department of Pharmaceutical Biology and Pharmacology, the Department of Pharmaceutics, and the Department of Pharmacy Practice.
World Health Organisation Collaborating Centre for Influenza	Parkville	The Centre undertakes research in the following fields: ▪ Immunology, ▪ Medical biochemistry and clinical chemistry, ▪ Medical microbiology, ▪ Physiology, ▪ Clinical sciences, ▪ Microbiology

The above listing does not include medical and clinical research carried out within Faculties and Departments of Universities. Detailed information about Melbourne University capability is contained in the University's *Research Report.*

▪ Cooperative Research Centres

Centre	Research Expertise
CRC for Cellular Growth Factors	Protein chemistry, molecular modelling, protein structure determination, genetic engineering, biotechnology, biology of blood and nerve cell growth factors, clinical trials, bioinformatics.
CRC for Cochlear Implant and Hearing Aid Innovation	Signal processing, speech science and psychophysics, electronics and communication engineering, clinical medicine, surgery, audiology, rehabilitation, computer modelling, implantable technology, biomedical research, paediatrics.
CRC for Vaccine Technology	Vaccine technology, molecular and cellular immunology, peptide and protein chemistry, vector biology.
CRC for Diagnostic Technologies	Antibody engineering, antibody/antigen detection, protein engineering, sensing reagents, genetic and infectious disease diagnostics, nucleic acid amplification.
CRC for Discovery of Genes for Common Human Diseases	Human genetics, molecular biology, statistical genetics, genotyping, positional cloning, therapeutics, diagnostics.
CRC for Asthma	Allergen Immunotherapy, Allergen Measurement, Clinical Trials, Epidemiology, Immunology and Pharmacology.

Not surprisingly, the extensive organisational network is associated with a considerable level of investment in research and development. This is indicated in the following section.

11.2 Research and Development Investment

The overall data provided in Part 2 indicate that just under 13 percent of Victoria's total research effort takes place in the health services sector. This is constituted broadly as follows.

Table 23: Health Services - Research and Development Expenditure 1996-97

Socio economic objective	Commonwealth Government $'000	State Government $'000	Higher Education $'000	Business $'000	Private Non-Profit $'000	Total Expenditure $'000
Clinical (organs, diseases and conditions)	4,214.1	32,746.3	80,851.9	23,954.0	60,609.1	202,375.4
Public health	2,129.8	10,616.2	26,700.7	5,943.0	14,007.5	59,397.2
Health and support services	45.9	4,622.8	13,169.2	3,005.0	370.4	21,213.3
	6,389.7	47,985.3	120,721.8	32,902.0	74,987.0	282,985.9
	2.3	17.0	42.7	11.6	26.5	100.0

Victoria has an advantage in a strong linkage between the State hospital system and the university medical schools. It is also significant that some of the private, not for profit sector, supports a very high proportion of the research effort.

The most significant component of research takes place in the public sector with 60 percent of research in medical and health sciences being undertaken by either Sate Government or the higher education sector.

The composition of research and development investment in the clinical and public health areas is provided in Tables 24 and 25.

Table 24: Clinical Services - Research and Development Expenditure 1996-97

Socio economic objective	Common-weath Government $'000	State Govern ment $'000	Higher Education $'000	Business $'000	Private Non-Profit $'000	Total Expend-iture $'000
130100 Not Classified			1,493.2	23,954.0		25,447.2
130101 Infectious diseases	3,316.6	10,291.1	7,426.6		318.5	21,352.7
130102 Immune system and allergy		37.5	4,618.2		8,822.6	13,478.3
130103 Blood disorders	25.1	327.6	1,282.1		391.2	2,026.0
130104 Neurological disorders		1,037.7	10,025.3		1,095.7	12,158.7
130105 Endocrine diseases (incl. diabetes)	592.3	756.7	4,851.2		3,885.5	10,085.7
130106 Cardiovascular diseases		1,412.5	8,512.1		11,201.0	21,125.7
130107 Inherited diseases		510.5	1,179.7		3,312.1	5,002.3
130108 Cancer and related disorders	272.4	5,122.4	3,555.0		18,135.5	27,085.4
130109 Surgical methods and procedures		2,024.3	920.4		3,086.7	6,031.4
130110 Respiratory diseases (incl. asthma)		141.0	3,020.7		463.6	3,625.3
130111 Hearing, vision and speech	7.6	28.2	7,698.6		2,393.6	10,128.0
130112 Oro-dental			3,491.7			3,491.7
130113 Digestive system		432.7	2,774.2		519.5	3,726.4
130114 Arthritis, bone and joint disorders		508.8	3,492.6		3,348.6	7,350.0
130115 Kidney diseases		1,253.9	1,916.7		938.0	4,108.5
130116 Reproductive medicine		2,015.7	4,663.5		2,473.8	9,153.1
130117 Skin and related conditions		37.5	309.2			346.7
130118 Other organs, diseases and conditions		5.5	2,805.6		125.9	2,936.9
130199 Clinical health not specific to particular organs, diseases and conditions		6,802.8	6,815.2		97.4	13,715.3
	4,214.1	32,746.3	80,851.9	23,954.0	60,609.1	202,375.4

The very high commitment to infectious diseases, immunology, neurology, cardiology, cancer research, hearing and reproductive medicine is apparent. In these areas Victoria

has an established international reputation. These trends are reflected in expenditure by fields of research (see below).

Information relating to research and development investment in public health is detailed below.

Table 25: Public Health - Research and Development Expenditure 1996-97

Socio economic objective	Common-wealth Government $'000	State Govern ment $'000	Higher Education $'000	Business $'000	Private Non-Profit $'000	Total Expend-iture $'000
130200 Not Classified			391.4	5,943.0		6,334.4
130201 Women's health		1,196.8	4,433.5		8.6	5,638.9
130202 Health related to ageing	106.6	133.6	2,136.5		2,085.0	4,461.7
130203 Child health		75.0	873.8		2,643.7	3,592.6
130204 Aboriginal health		608.9	98.7			707.6
130205 Substance abuse		367.2	609.9			977.1
130206 Occupational health (excl. economic development aspects)		140.0	2,027.9		30.3	2,198.2
130207 Environmental health	477.8	7.5	269.9			755.2
130208 Mental health	487.6	4,166.6	4,608.5			9,262.7
130209 Disease distribution and transmission		26.2	647.6			673.7
130210 Preventive medicine		1,341.8	775.9		8,401.1	10,518.8
130211 Dental health			419.8			419.8
130212 Nutrition		596.8	964.4			1,561.2
130213 Food safety	1,057.8		58.6			1,116.4
130214 Health status (e.g. indicators of "well-being")		88.8	316.5		51.0	456.3
130215 Social structure and health		97.2	205.4		10.0	312.6
130216 Behaviour and health		671.4	760.3			1,431.7
130299 Public health n.e.c.		1,098.4	7,102.1		777.8	8,978.3
	2,129.8	10,616.2	26,700.7	5,943.0	14,007.5	59,397.2

The data indicate a very strong commitment to mental health and preventative medicine.

Victoria accounts for nearly 42 percent of national research and development expenditure in Medical and Health Services. The fields of research that contribute to this large commitment are reflected in the following Table 26.

Table 26: Proportion of Australian R& D Expenditure on Medical and Health Services in Victoria

	Total Public Sector	Victoria Public Sector	Proportion Victoria
	$'000	$'000	%
100100 Immunology	21,367	7,995	49.4
100200 Medical Biochemistry And Clinical Chemistry	12,608	2,846	25.6
100300 Medical Microbiology	14,727	5,712	67.1
100400 Pharmacology	19,720	8,814	46.0
100500 Physiology	19,331	5,275	30.1
100600 Neurosciences	28,903	9,545	36.3
100700 Clinical Sciences	130,768	56,920	48.8
100800 Public Health Research	57,410	20,183	47.2
100900 Health Services Research	35,724	7,746	23.2
109900 Other Medical And Health Sciences	12,146	2,012	18.2
	352,704	172,508	42.0

The data reflect Victoria's strength in Immunology, Microbiology, Pharmacology, Clinical Sciences and public health research.

11.3 Capability indicators

Information provided by survey respondents is set out in Table 27.

Table 27: Research Capability in Health

Fields of Research	No of Capabilities Identified	Total Capability Level	Average Capability	No of FOR classes	Count of Orgs
Agricultural Sciences	1	2	2.0		
Applied Sciences and Technologies	1	4	4.0		
Biological Sciences	26	57	2.2		
Mathematical Sciences	2	8	4.0		
Medical and Health Sciences	40	113	2.8		
Physical Sciences	1	4	4.0		
Social Sciences	2	8	4.0		
	73	196	2.7	37	12

The major area of capability is in medical and health sciences and the biological sciences. However, the low level of capability assessment across the fields of research for medical and health sciences is of some interest. In all probability, it reflects the low response and participation rates in the Survey by the major medical research institutes. It may also be a reflection that Victoria's capability in these areas is slipping on a world class comparative basis.

11.4 Comments and Issues Raised in Focus Groups and Consultations

11.4.1 Comments

Victoria has a very strong science base and technical skills, based on a long tradition of highly competitive peer-reviewed public funding. There are also very close linkages between the public health system and university medical faculties and institutes.

The institutional and organisational framework is quite extensive – and has strong linkages. There are active research and development initiatives on all major campuses, and there is a movement towards aggregation of capability for critical mass and including/justifying further expenditure and business support, for example, Bio 21 at Parkville and the Monash Research Precinct. Increased cooperation is occurring between cancer researchers, and to build on strengths in stroke, hypertension and clinical trials

The University of Melbourne has adopted an innovative approach to IP management, including early assignment of property to the inventor and use of funds from the float of Melbourne IT, via Melbourne Enterprises, to place business managers in each Faculty to ensure that commercialisable technology is identified, protected and exploited

There appears to be more interaction *between* institutions and universities than in other States/Territories. This could be used to help the medical science and technology community interact/network with the commercial sector in fields such as cardiovascular and neuroscience.

Other factors sustaining Melbourne as a high investment location are:

- The moves by high-profile business-people (such as Kerry Packer) into biotech resulting in increased availability of venture capital for this sector; some successes now apparent (Axon, Circadian, etc)
- Some industry-specific events, such as the Commercialising Health Innovations Forum (CHIF) held in Melbourne in Oct 99, as a networking event for investors, advisers and investees

- The Technology Commercialisation Program (from Nov 99), using private providers to provide assistance to entrepreneurs
- Positive attributes of Melbourne as a whole.

11.4.2 Main Issues Raised

The main issues identified in documentation and discussion included:

- A strong desire to take technologies further along the 'value curve' rather than simply early licensing for small royalties, yet still not as far as could go
- Some Quality-Accredited facilities are under-utilised, i.e. potential to adopt some of the emerging technologies, example AMRAD ICT
- A need for up-stream skills to extract value from patents, i.e. a need for management skills in commercialisation
- The 'clinician researcher' is under threat due to introduction of case mix funding arrangements; there are some current attempts by NHMRC to redress this problem
- A need for some catalyst to ensure the interaction/existing networks are extended *beyond* the research sector
- Whether or not Victoria should 'pick winners', and who would be able to do this; whether in fact an advisory sounding board was what was required
- The extent to which the underlying cultural and systemic issues could be solved within State borders
- Whether or not there is a seed-stage funding gap, or simply a lack of skills to access ready-capital
- A high degree of 'exposure' or lack of confidence of the majority of academics in the commercialisation process associated with a problem that scientists do not always appreciate the need for professional/ management assistance
- The public grants system does not allow for much discretionary spending by universities
- The manufacturing infrastructure is limited in Victoria, especially GMP and scale-up, resulting in a need to use overseas facilities; this raises the question about the appropriate structure of the bio-industry that Victoria will build
- Salary levels for young scientists make it hard to attract best and brightest; subsidies being offered in other States can make it even harder.

11.5 Initiatives Proposed

A number of specific initiatives were identified in discussion and consultation:

- Skills enhancement initiatives that are focused on increasing the pool of 'deal-makers' in Victoria
- Educative programs for scientists; more PhD, MBAs; optional commercial subjects in technical PHD courses, etc
- Extending assessment/credibility criteria for academics to include commercially-oriented successes
- Mechanisms to break the traditional scientific credibility cycle / hierarchy, especially where this suppresses young entrepreneurs

- Initiatives to enable mobility between sectors, eg sabbaticals in industry; graduate-in-industry programs, yet query over whether existing (IRDB/ISR) mechanisms are being utilised (for graduates); require transferability *back into* the academic sector without penalty (eg reduced publications); could involve for example finance to subsidise teaching; would need to address potential IP complications
- A need for government subsidies for non-R&D expenditure in areas such as business planning, market research, etc
- Initiatives to capitalise on existing international networking, for example (inwards) visit by a pharma acquisitions manager (delegations model); and (outwards) conference attendance by academics (exposure model)
- Build on leadership, existing 'luminaries', several of whom will have high-level relationships / consulting agreements with pharma companies, to bring young people in, for mentoring etc.

Some suggestions were made for a database specifically aimed at increasing networking across the sectors (including finance and industry), providing information' about who owns which patents, what skills, what contacts, akin to ABA database but '100 times better'; would require on-going maintenance. There was also discussion about a possible mechanism to add loading to some salaries to attract/retain bright future entrepreneurs in 'areas of the future', eg bioinformatics.

Notwithstanding the focus on commercialisation of research and development, the capacity and capability in the sector has been built up by achieving *public health outcomes*. Such outcomes have a capacity to contribute to economic development by lowering health costs and building further depth into the research base.

12 Environmental Industries

12.1 Capability

▪ CSIRO

Division/Unit	Location	Research Capability
Atmospheric Research	Clayton South, Aspendale	CSIRO Atmospheric Research conducts world-class research into our atmospheric environment and provides advice and applications for the benefit of Australia. In particular, the Division serves the community through outcomes that provide benefit to industry and the economy, environmental benefit, social benefit and support to national and international objectives. Specifically, the Division addresses issues such as urban and regional air pollution, acid deposition, the enhanced greenhouse effect, ozone depletion, climatic variability and severe weather. Research tools include computer-based climate and atmosphere models as well as remote sensing and other atmospheric monitoring instruments. Key stakeholders include Commonwealth and State Environment Departments, and energy and mineral resource companies.

▪ Bureau of Meteorology

Division/Unit	Location	Research Capability
National Climate Centre	Melbourne	As one of the World Meteorological Organization's global environment emergency response centres, the NMC is also responsible for covering the entire southern hemisphere in the event of an environmental disaster. Forecasting results are distributed to Australia's seven Bureau Regional Officers which then issue forecasts to the public.
Bureau of Meteorology Research Centre	Melbourne	In addition to being a leader nationally and internationally in meteorological and oceanographic science, the Centre provides the research infrastructure which underpins all Bureau of Meteorology services and products. The Centre's research collaborators are extensive, including: (in Australia) various arms of the CSIRO and almost every University in the country; and (overseas) the National Center for Atmospheric Research in the US, NASA also in the US, the Hadley Centre for Medium-Range Weather Forecasts in the UK; and many others. Industry links are also strong in the aerospace industry.

▪ Cooperative Research Centres

Centre	Research Expertise
CRC for Catchment Hydrology	Catchment hydrology, soil physics, vegetation dynamics, hydrologic modelling, fluvial geomorphology, flood estimation, river hydraulics, irrigation and drainage, sediment transport, water quality, pollutant modelling, socio-economics, environmental management, statistics
CRC for Freshwater Ecology	Flow-related ecosystem processes – e.g. impact of flow regulation on aquatic systems, environmental flow allocation. Restoration ecology – e.g. recovery of disturbed systems, stream rehabilitation case studies. Conservation ecology – e.g.biological diversity in freshwater systems, threatened aquatic species. Water quality and ecological assessment – e.g. ecological risk assessment, assessment of habitat condition.

Centre	Research Expertise
CRC for Water Quality and Treatment	Health risk assessment related to water quality, cyanobacteria and other pathogens, natural organic matter, water treatment technologies, biofilm development, disinfection by-products.
CRC For Southern Hemisphere Meteorology	Dynamical meteorology, atmospheric chemistry and physics, numerical weather and climate modelling, atmospheric general circulation, stratospheric dynamics, data analysis and inverse methods.

▪ University Research Centres

Research Centre	Host University	Capability Overview
The Centre for Environmental Applied Hydrology	Departments of Civil and Environmental Engineering and Geography and Environmental Studies, University of Melbourne.	Specific expertise in all aspects of surface and groundwater hydrology, hydraulics, and fluvial geomorphology including: ▪ standard engineering and stochastic hydrology, ▪ environmental hydraulics and hydrology including water quality and ecological issues, ▪ environmental monitoring and data collection systems, ▪ global scale surface and atmospheric processes, ▪ geomorphology and riparian/river management, ▪ river and lake hydrodynamics, ▪ groundwater issues, and ▪ contaminant transport. Research is undertaken in all these areas but are also active in consulting and are able to respond directly to clients. The Centre specialises in interdisciplinary work requiring hydrological, biological and ecological input and are actively involved in integrated catchment management projects including those with major community input.
Centre for Environmental management	University of Ballarat	The Centre was established in 1995 to consolidate the University of Ballarat's position as a centre for industry-linked environmental teaching, research and consultancy. The Centre comprises an interdisciplinary group with expertise in flora and fauna; soils; hydrology; management planning; and coastal, wetland, rangeland and forest management. In December 1996, following an external review process, the Centre for Environmental Management was named as one of three priority research centres.
Centre for Applied Colloid and BioColloid Science	Department of Applied Chemistry at Swinburne Institute of Technology	Swinburne's Centre for Applied Colloid and BioColloid Science was established in 1980. The Centre promotes the development of both applied and contract research in colloid and surface science. The Centre remains at the forefront of Australian scientific research in terms of technological applications of this field to Australia's scientific industry. The Centre has brought together expertise in several fields of physical chemistry (surface and colloid chemistry), analytical chemistry, engineering, biotechnology and microbiology (biocolloid science) to focus effort on interfacial phenomena where material properties are dominated by surface interactions. Teaching of applied colloid science at both undergraduate and postgraduate levels and through short courses is undertaken by the Centre. It operates as a contact point for visiting members of staff from other

Research Centre	Host University	Capability Overview
		academic institutions, companies and government authorities, both local and overseas. It is involved in many research activities which can be broadly classified into four main areas; BioColloid Science, Dispersion Technology; Surface Science and Waste Management Systems.
Centre for Environmental Safety and Risk Engineering	Victoria University	No Details
Palaeo-Environments Group	Deakin University	The Palaeoenvironments and Global Change Group is a provisional research priority area of Deakin University and a research development of the Faculty of Science and Technology of Deakin University. As a research group within a university a major function is education and training. Part of that training involves planing undergraduates (BSc Hons) students and postgraduates with industry. Other students add to the baseic knowledge of geology of the state through their projects if Victorian based - the results of which may be subsequently picked up by industry.
Water Studies Centre	Monash University, Faculty of Science	The Water Studies Centre is a multidisciplinary research centre within the Chemistry department at Monash University, and is a major partner in the CRC for Freshwater Ecology. The WSC operates a multidisciplinary research portfolio that focuses on four broad areas: ▪ Biogeochemical cycling ▪ Real-time instrumentation ▪ Aquatic colloidal chemistry ▪ Aquatic biology (with Melbourne Water) The WSC has established a successful technology exchange program to ensure its research is taken up by the water and natural resource management agencies. It has established collaborative links in Indonesia, Thailand, Philippines, the UK, USA, Germany, Sweden, Italy, South Africa and Lesotho.

12.2 Investment

Victoria has a significant capability in science and technology in the environmental sector. Melbourne is the location of the Bureau of Meteorology which has a number of significant research facilities.

Table 28: Environment Industries - Research and Development Expenditure 1996-97

Socio economic objective	Commonwealth Government $'000	State Government $'000	Higher Education $'000	Business $'000	Private Non-Profit $'000	Total Expenditure $'000
Environmental knowledge						
. Climate and atmosphere	22,224.0	219.6	2,952.2	0.0	0.0	25,395.9
. Ocean	1,026.3	0.0	75.0	0.0	4.8	1,106.0
. Water	148.2	2,162.8	3,530.1	3,410.0	14.3	9,265.4
. Land	104.9	4,327.6	1,624.6	0.0	9.5	6,066.6
. Nature conservation	1,164.9	9,843.6	6,209.1	0.0	749.4	17,967.0
. Other	297.0	625.5	2,718.6	215.0	24.6	3,880.8
	24,965.3	17,179.2	17,109.6	3,625.0	802.6	63,681.6
	39.2	27.0	26.9	5.7	1.3	100.0
Environmental aspects of economic development	10,622.7	889.3	5,103.0	1,117.0	9.5	17,741.5
	59.9	5.0	28.8	6.3	0.1	100.0

Socio economic objective	Commonwealth Government $'000	State Government $'000	Higher Education $'000	Business $'000	Private Non-Profit $'000	Total Expenditure $'000
Environmental management and other aspects	3.8	4,010.2	3,774.2	4,315.0	14.3	12,117.4
	0.0	33.1	31.1	35.6	0.1	100.0

The data reflects the contribution of the Bureau of Meteorology to Victoria's research base.

12.3 Capability Indicators

Indicators of research capability in environmental output areas is provided below.

Table 29: Research Capability in Environmental Areas

SOE	Fields of Research	No of Capabilities Identified	Total Capability Level	Average Capability	No of FOR classes	Count of Orgs
Environmental knowledge						
	Agricultural Sciences	2	6	3.0		
	Biological Sciences	30	93	3.1		
	Earth Sciences	6	21	3.5		
	Social Sciences	7	21	3.0		
		45	141	3.1	22	4
Environmental Aspects of Economic Development						
	Applied Sciences and Technologies	5	16	3.2		
	General Engineering	5	19	3.8		
	Information, Computer and Communication Technologies	4	16	4.0		
		14	51	3.6	14	5
Environmental Management Other Aspects						
	Agricultural Sciences	4	8	2.0		
	Applied Sciences and Technologies	19	38	2.0		
	Earth Sciences	2	4	2.0		
	General Engineering	1	2	2.0		
	Information, Computer and Communication Technologies	3	6	2.0		
	Social Sciences	7	14	2.0		
		37	74	2.0	17	2

It is of interest that the two organizations that responded to environmental management rate capability as quite low.

12.4 Comments and issues Raised at Focus Groups and in Consultations

12.4.1 Issues

Victoria is giving a priority to a "clean green image/brand". There is also a gradual but progressive strengthening of linkages between knowledge and skill providers (CSIRO, CRCs, universities) and industry and government agencies. Consulting companies may be an essential intermediary in this sector between the knowledge producers and users.

The EPA has played a key role in Victoria in bringing industry and regional groups together to examine and respond to problems of common interest, and in organising the service providers to link with industry and local government, for example, Envirolinx.

There is a high level of trust (social capital) amongst the various components of the sector. However, the Victorian universities still see each other as primarily in

competition, and look for collaboration with universities outside the State that are not in direct competition for students.

Victoria has considerable strengths/leadership in water management and environmental management.

The Bureau of Meteorology, CSIRO and EPA and Monash University together have substantial expertise and resources in atmospheric aspects of environmental matters, but have not established effective consultation and cooperation.

12.4.2 Issues

The main issue is to build more strongly on and capture benefits from the networks that CRCs seed. Other factors of note include:

- Essential tension between the value of independent research/expertise and getting close to the customer
- Universities practice very little succession planning; when a recognised research leader leaves/retires, strong research teams often are allowed to dissipate quickly, and valuable infrastructure simply neglected or trashed/firesaled
- Similarly. the decision of a company to move out of research, for example, BHP, leads to a massive loss of infrastructure of all kinds.

12.5 Initiatives Proposed

A number of initiatives were identified from material provided to the Survey Team:

- Establish a mechanism/organization that has the expertise and experience of building linkages so that each CRC proposal/ new collaborative initiative does not have to reinvent this difficult wheel
- Encourage universities to engage in some collective succession planning, perhaps initially for research leaders within 5 years of retirement, as a basis for rationalisation and collaboration
- Build on the EPA model of network development, and where possible add an industrial cooperation component into groupings formed for environmental objectives
- Promote and publicise ‘Smithson-type’ companies in Victoria.

13 Natural Sciences, Technologies And Engineering

13.1 Capability

▪ University Research Centres

Research Centre	Host University	Capability Overview
Monash Science Centre	Monash University, Faculty of Science	The Monash Science Centre has been functioning since 1993 as a significant contributor to solid science communication and education. It is one of the few centres in the world that deals with an in-depth communication of science content and the practice of science. It is also one of the few centres in the world that frequently interfaces research scientists and their programs with the general public, especially primary school children. The Monash Science Centre has take the model of the Lawrence Hall of Science at the University of California at Berkeley as one to which it aspires, and some of its staff have been mentored by staff at that institution.
International Development Technologies Centre	Department of Civil and Environmental Engineering of the University of Melbourne	The International Technologies Centre is a multi-disciplinary academic and research unit . The term "development technologies" involves the application of the traditional and emerging engineering sciences and disciplines to the problems and needs of the developing countries. The philosophy of the Centre is that developing countries deserve technologies that have been specifically designed and adapted to their own particular, economic, social and cultural needs and not just obsolete or second rate technologies from "developed" countries. Such technologies may be "high" or "low", complex or simple, cheap or expensive. They may involve hardware - machines, vehicles, buildings, dams and water channels, food, chemical or mineral processing equipment etc. Alternatively they may involve "software" - systems for design control, management, planning, maintenance of construction, manufacturing, agriculture, irrigation , transport industries and the associated education and training of staff.
UNESCO Supported International Centre for Engineering Education	Monash University, Faculty of Engineering	UICEE is the world's first and only centre of its kind in engineering education. It is located in the Faculty of engineering at Monash University and the establishment of the Centre is widely regarded as a most significant undertaking in the globalisation of engineering education. UICEE's commission is human resource development within engineering trough engineering education, a dual brief in its concern with the two principal facets of education: teachers and students - the instructors and future practitioners of engineering. To this endi the Centre's work involves the development of pedagogy, through research and development of coursework, software and teaching methodologies, as well as of engineering curricula in consultation with industry

13.2 Investment

This category covers basic and “discovery” research undertaken within scientific disciplines. The data indicate a very substantial commitment to research in the biological

and medical and health sciences. A significant proportion of the latter discovery effort is supported by private, non-profit arrangements.

Table 30: Natural sciences, technologies and engineering - Research and Development Expenditure 1996-97

Socio economic objective	Commonwealth Government $'000	State Government $'000	Higher Education $'000	Business $'000	Private Non-Profit $'000	Total Expenditure $'000
Mathematical sciences	109.1	0.0	10,695.3	0.0	0.0	10,804.4
Physical sciences	0.0	0.0	14,442.5	33.0	0.0	14,475.5
Chemical sciences	0.0	0.0	14,248.1	0.0	0.0	14,248.1
Earth sciences	0.0	4.1	5,827.2	7.0	0.0	5,838.3
Information, computer and communication	0.0	0.0	15,491.7	0.0	0.0	15,491.7
Applied sciences and technologies	137.8	0.0	11,224.5	1,042.0	0.0	12,404.3
General engineering	0.0	0.0	6,598.0	603.0	0.0	7,201.0
Biological sciences	299.9	2,954.0	31,671.7	0.0	2,280.2	37,205.8
Agricultural sciences	0.0	0.0	839.8	834.0	269.7	1,943.5
Medical and health sciences	0.0	135.3	17,354.7	4,102.0	7,565.7	29,157.7
	546.8	3,093.3	128,393.5	6,621.0	10,115.6	148,770.2
	0.4	2.1	86.3	4.5	6.8	100.0

As would be expected the data indicate high levels of investment by the higher education sector as well as investment by the private sector in medical and health sciences.

13.3 Capability

Information on research capability indicators is provided below.

Table 31: Research Capability in the Natural Sciences

SOE	Fields of Research	No of Capabilities Identified	Total Capability Level	Average Capability	No of FOR classes	Count of Orgs
Natural Sciences						
	Agricultural Sciences	2	6	3.0		
	Applied Sciences and Technologies	25	85	3.4		
	Biological Sciences	24	79	3.3		
	Chemical Sciences	45	155	3.4		
	Earth Sciences	12	42	3.5		
	General Engineering	10	30	3.0		
	Mathematical Sciences	3	9	3.0		
	Medical and Health Sciences	17	53	3.1		
	Physical Sciences	6	21	3.5		
		152	502	3.3	110	15

14 Conclusion

The information provided in this Party of the Report is extensive. It has served to indicate the levels of STI capability and investment in major output areas and to provide some comments about current strengths, and weaknesses, in the STI resource base and areas for improvement.

The information points to a substantial strength in Victorian STI Capability in the areas of:

- Plant and Animal Production, relating in particular to research and development capability
- Minerals, particularly minerals processing
- Manufacturing, particularly capital intensive processes involving information technologies and materials science
- Information and communications
- Health and Medical Services.

The areas where respondents to the STI request for information have identified gaps and suggested are for investment is set out in Part 4.

Part 4: Initiatives Proposed by Respondents for STI Investment

1 Introduction

In this Part of the report we have set out specific proposals for infrastructure investment put forward by respondents to the "Request for Information" circulated in December/January. The proposals were put forward in response to the request to identify specific gaps in the State's STI infrastructure.

The proposals are grouped as follows:

- Facilities and equipment
- Capacity and capability building
- Investment in people
- Cooperation, collaboration and networking
- Support for commercialisation.

The content of many of the proposals is reflected in the analysis and recommendations contained in earlier Parts of the Report. However, we have not made any comments about the economic benefits of the proposals.

2 Facilities and Equipment

Organization	Comment
Aerospace Technologies of Australia [ASTA Components]	The technical infrastructure capability gaps seen paramount to ASTA's future success are tabulated below:- ▪ Infrastructure in Aluminium Castings technology ▪ Fabrication and Assembly Automation ▪ Design/Manufacturing Optimisation for efficient Concurrent Engineering of new parts ▪ Understanding of resin characteristics and behaviour for liquid moulding ▪ Damage behaviour of metallic structures ▪ Rapid Prototyping ▪ Contemporary low cost tooling design ▪ Differential Scanning Calorimetry [DSC] polymer characterisation ▪ Advanced CAD/CAE logistical operation
Australian Animal Health laboratory	Pharmaceutical companies and research institutes often need to access commercial fermentation and cell culture capability, for production of vaccines and recombinant gene products. This needs to be done to Good Manufacturing Practice (GMP) in order to enable them to be evaluated. Currently, the only GMP facility in Victoria is owned and operated by CSL Limited. This is made available on a commercial basis to outside parties at times when CSL Limited does not require the facility. There appears to be a significant under capacity in Australia for this type of service and a number of Victorian institutes are keen for an additional facility to be developed. CSIRO's Australian Animal Health Laboratory has an uncommissioned vaccine production unit that could be activated with input of resources, to convert to GMP standards, and to install the required equipment. This facility has all the relevant services required by a GMP facility, including gas, water, electricity, steam, ducted liquid nitrogen and HEPA filtered air supply, together with the required isolation areas. It could then be leased or made available to commercial parties through some other arrangement. The development of an additional, small-scale GMP facility for pharmaceutical and biological products would place Victorian biotechnology in a very competitive position.
Australian Neuroscience Society Incorporated	It is essential that Victoria be placed at the front of efforts to exploit the molecular information that will flow from sequencing the human genome. To this end, Victoria needs to ensure adequate funding of core facilities. Some are already in place and well funded. Others need to be better and more reliably supported, both for equipment and professional salaries, including: - Bioinformatics - Transgenic animal facilities and technology - cDNA arrays/chip technology Attracting the best to Victoria It is imperative that Victoria retains its best research scientists and prevents them being attracted interstate and overseas. It is also of immense value to the state to attract the best research workers to bring their ideas and their commercial potential here, rather than go elsewhere. Funding conditions for research, both for salaries and for equipment and running costs, remain poor in Australia compared with overseas. Other states, notably Queensland, have made a concerted effort to improve conditions for biomedical research in their state, and are having success at building and strengthening their climate for research, from which commercial benefits will undoubtedly flow. This initiative is already attracting excellent workers to Queensland: the announcement of Prof Mark von Itzstein's move from Monash University to Queensland is a recent example. Victoria needs to provide incentives for the best research workers to place themselves in Victoria. To this end,

Organization	Comment
	mechanisms that are administratively simple need to be found for providing additional financial support for excellent research and for excellent scientists. Several mechanisms might be considered; matching all competitively won grant dollars over a certain base level (say $200,000 per year) with state funds, or matching all 5 year grants with state funds, or rewarding registration of provisional patents or publication in certain high profile journals with financial bonuses. Whatever the mechanism, the focus needs to be on rewarding the best research scientists, not all, so that this is an incentive for excellent researchers to locate themselves in Victoria. Mechanisms that provide financial rewards to the individual scientists are unlikely to be administratively simple or effective. Typically, it is the ease of adequate funding for their research that is attractive to research scientists.
Australian Pulp and Paper Institute	Gaps which are apparent within Victoria's STI infrastructure relate to our ability to carry out the necessary research for product development for the new digital printing and decorating technologies. These inadequacies appear as the Institute is seeking to put together a co-operative research proposal (in the form of a CRC) which will address these technologies and stop associated jobs going off shore.
CDS Pty Ltd	Where resources are not available in Victoria, the company has looked elsewhere. Two areas (not strictly STI?) where difficulties have been experienced are the lack of performance standards for equipment (where manufacturers can make patently false claims), and the availability of facilities for the demonstration of new or innovative equipment (where it is necessary to point to an existing user before anyone is prepared to become a user).
Centre for Material and Surface Science	A synchrotron for Victoria: Purchase cost $100-150 million - CMSS has been intimately involved in the SIRF- sponsored Industrial Synchrotron Round Table (ISRt). ISRt is tasked with raising industry awareness of synchrotron technology. As major synchrotron users, CMSS staff are currently forced to travel to Germany, USA, and Japan to conduct experiments. Extension of CMSS successful industrial surface analysis program to industrial clients is not possible under the current access arrangements.
Ceramic Fuel Cells Ltd	Access to state of the art materials and interface characterisation facilities will assist CFCL in the development of world best solid oxide fuel cell technology but CFCL's usage alone could not justify its establishment. In addition, infrastructure manufacturing process development including automation could be useful.
Composite Fabrication Centre and CRC for Polymers	Specific gaps relevant to the CRC for Polymers include: 1. Facilities for pilot scale polymer manufacture to enable cutting edge research in the field of polymer synthesis, such as that being undertaken by the CRC for Polymers and CSIRO Molecular Science, to be developed to produce the quantities of polymers required for the evaluation material properties, prove the processes and facilitate the eventual take up of technology by industry. Currently much such scale up work must be carried out overseas. These facilities would include small to medium scales reactors with appropriate on-line monitoring equipment and a significant upgrade to reactive extrusion capability to allow polymerisation to be undertaken in the extruder (e.g. tangentail twin screw extruder). 2. Improved facilities for the effective characterisation of the molecular weight and composition of synthetic polymers. There have been significant developments in these fields over the last few years and Australia has not kept pace with the changes. Equipment includes mass spectrometry with resolution and mass range appropriate for characterising synthetic polymers and novel chromatographic methods (including multi-detector gel permeation chromatography, temperature rising elution chromatography and three dimensional high performance liquid chromatography. 3. Equipment for the foam extrusion of polymers with high melt strength to enable pilots scale production of foam articles. This facility would also allow the more rapid evaluation and development of such materials that are currently of great interest worldwide. They possess high strength, low density, and can be

Organization	Comment
	based on polymers that are more readily recyclable. Applications such as foamed polymers are in packaging, and automotive products, etc.
	4.. New methods for surface characterisation of polymeric materials. Atomic force microscopy enables the surfaces of materials to be visualised at the atomic level. New developments in this technique enable much more information to be obtained on the physical, thermal and chemical composition.
CSIRO Division of Atmospheric Research	CSIRO Atmospheric Research's capabilities are, to a large extent, dependent on ready availability of high-performance computers. We are one of the largest supercomputer users in the world, but currently get little support from the Victorian Government. In fact, we make extensive use of Queensland Government IT facilitates.
	Victorian Government support for a scalar multi-processor computer would enable CSIRO Atmospheric research to act as a demonstration site, showcasing to industry, Australia and the world, the high level of IT innovation and application in Victoria. This would be a highly effective way of encouraging use of modern, high-performance supercomputing technology throughout the State, using the existing management and technical infrastructure.
	There would be significant benefits to the State if the Victorian Government were to contribute to the CSIRO/Bureau of Meteorology supercomputer facility. Such a contribution would ensure that the facility would be better utilised by research groups and industry. Undoubtedly, there would be distinct economic advantages for Victoria if scientists and industry were able to gain access to one of the world's most powerful computing facilities.
Demodairy	If assistance were provided to DemoDAIRY to upgrade its milk harvesting facilities, the direct and indirect benefits would be multiplied many times. Improved access to accurate information for southwestern dairy farmers (who have missed out in the past because no public dairy research facility was provided in the dairying region in the South West) will support the rapid growth of the industry in the area. Community ownership of this facility also means that the community, not government is responsible for ongoing maintenance and replacement.
Department of Chemistry, Latrobe University	In the Bundoora area, the future collaboration between LTU chemistry and the Victorian EPA and other organisations (e.g. AGAL, Police Forensic Labs and RioTinto) should be strengthened by ensuring that advanced analytical equipment is accessible to all groups in the locality (much like it is in the Parkville area).
	Key equipment to be considered includes ICP/MS, NMR, MS, surface analytical equipment, thermoanalytical, X-ray, electroanalytical, CE and chromatography.
	The department desperately need s to upgrade the 300 MHz NMR spectrometer. It is a very heavily used hybrid machine. The console was built in 1985 and requires an upgrade because of its age and limited capabilities. The magnet has many years of life left.
	The department is aware of the development at CSIRO Clayton of a Microwave Reactor specifically designed for chemical laboratory use. This purpose built machine has applications in synthetic chemistry, polymer preparation, biotechnology and geology. The Australian technology behind the microwave reactor and the potential microwave chemistry and techniques have for advances in academic and commercial research makes this instrument an important facility to be acquired by local Universities.
	The La Trobe Chemistry department is well placed to use one of these reactors in numerous applications in its own research program and to provide access to other users in the commercial field. This microwave technology is an important emerging field for research and application and one that is currently not available in Australian universities.
	The department would also like to upgrade its mass spectrometry instruments to complements the machines currently held with extra capabilities which will substantially add tot the interest from external users and to the teaching and research areas of the departments activities. Specifically, an ICP-MS (cost $1.0M) and a TOFSIMS ($1.2M) would be invaluable acquisitions.

Organization	Comment
DSTO – Micro Electro-Mechanical Systems	For Victoria (or Australia) to participate in the emerging micro-machining revolution in manufacturing a complete prototyping facility for MEMS devices is needed. An estimated cost of between $25-30M spread over 3-4 years to set up a facility has been provided. The Victorian Micro Fabrication Facility (VMFF) would offer the following services to industry and research establishments: ▪ a clean-room for MEMS fabrication with an appropriate level of CMOS circuit fabrication to make “Smart” MEMS devices ▪ computer aided design and modelling tools ▪ a single point interface to other (local and off shore) MEMS and CMOS fabrication facilities. Further information on this proposal has been provided
Ellinbank Dairy	A key gap in Victoria's STI infrastructure, from the point of view of the agriculture industry, includes glasshouse facilities to undertake detailed agronomy work.
Food Science Australia	A facility for commercial process scale-up and start-up for value added food, nutraceuticals and bioproducts is required
Industrial Research Institute, Swinburne (IRIS)	The following is a brief list of equipment that the Industrial Research Institute Swinburne could make good use of: ▪ Frequency quadrupled laser for micromaching and plasma analysis; ▪ 300GHz high power source for biotechnology and micro-processing of materials; ▪ Synchrotron for micromanufacturing, advanced lithography, surface analysis, protein X-ray cystallography, etc.; and ▪ A class 1 clean room facility for semi-conductor, mircomachine, and biomaterial fabrication.
Institute of Animal Science	Recent investment through the Science Technology and Engineering Initiative has provided a much-needed boost to VIAS’ capacity in molecular genetics and genomics. This adds to VIAS’ strategic capacity in platform technology in recombinant vaccine development and genetic engineering. Further commitment to the ongoing support of these programs through the STI (or other) initiative is needed to maintain VIAS strategic advantage in these fields of animal science and to maximise the return from these investments in the medium to long term.
Institute of Dryland Agriculture	If NRE’s involvement in development of GMO products is endorsed, the Institute will require additional facilities (handling areas and glasshouses) to ensure that products can be isolated to standards demanded by GMAC and expected by clients. Capacity to undertake weed research as an important input into integrated farming systems of the future Major potential gap in oilseeds laboratory equipment if NRE establishes it's own oilseed analytical capacity (much of the current routine work is done through a joint venture with AgSeed Research). Significant purchases ($300-400,000) would be required eg. HPLC, Leco Protein Analyser and a second NIR etc.
Institute of Sustainable Irrigated Agriculture	Gaps in Victoria's STI infrastructure capability relevant to the Institute of Sustainable Irrigated Agriculture fall into three main categories. ▪ There is a need for more comprehensive modeling of a variety of systemic factors of importance to irrigated agriculture, including catchment scales, soil/water/plant/atmosphere systems, salinity, farm management practices, etc. ▪ Second, there is a need for a selection of more specialized equipment in relation to laboratory analysis and field sampling (e.g. ICP Mass Spectrometer) which is too expensive to purchase for individual projects. ▪ Finally, there is a need for more comprehensive data base design and management in a number of fields of generic application to irrigated agriculture.

Organization	Comment
Joint Centre for Crop Improvement	The Joint Centre has been a highly successful collaborative venture that has made a very significant contribution to the Victorian and Australian Grains Industries through the generation of research data and the training of postgraduate students and research fellows. It is known nationally and internationally for its research and training roles. It is important to recognise that this position has been achieved by utilising existing core resources of its partners and some new resources accessed by the partners through the Centre. The Centre has had many of the achievements of a CRC but without the resources available to a CRC. The major limitations to further expansion and future development of the Joint Centre are senior staff to supervise postgraduate students and research fellows and specialised infrastructure. The staff issue is being addressed through strategic senior appointments by both the University and Agriculture Victoria. Infrastructure is therefore the outstanding limitation. Gaps in infrastructure capability are: ▪ Equipment and laboratories to allow an expansion of research and training in agronomy and farming systems at Horsham. The facilities would be shared between the University of Melbourne's Longerenong College and the Victorian Institute for Dryland Agriculture. The priority for expansion of these areas was identified by the 1997 Review of the Joint Centre (copy enclosed) ▪ Laboratory space and glasshouses for recombinant DNA and plant physiology research a Parkville ▪ Appropriate accommodation for the expanding student body at Horsham. At least five and probably more, postgraduates have/will commence work at Horsham in 2000
MAFRI	The construction of quarantine laboratories is required. There are such facilities in Victoria but none have the capacity for an aquatic focus.
Mental Health Research Institute of Victoria	It is submitted that, in addition to 'filling gaps,' Victoria's STI infrastructure strategy should be directed to maintaining, and taking advantage of already existing infrastructure. In this regard, it is important to note that the important contribution which MHRI makes to Victoria's intellectual capital may be threatened in coming years by closure of Royal Park Hospital, as part of the mainstreaming of mental health services by Australian governments. MHRI was established adjacent to this Hospital for reason of access to clinical wards and patients. The closure of the Hospital will deprive MHRI of its ready and reliable access to patients and clinical colleagues. This may rob MHRI of momentum at precisely the time when there are enormous opportunities for advances in brain research. By supporting MHRI at this critical time Victoria's STI infrastructure strategy could make a substantial and cost-effective contribution to shoring-up Victoria's intellectual capital in brain research into mental disorders.
Pastoral and Veterinary Institute	A requirement is capacity to overcome soil constraints to productivity as an important input into integrated farming systems for the future - the major gap is in PC2 grade laboratories and glasshouses to ensure biotechnological advances in pasture plant breeding are capture in new cultivars. Research of this type must be conducted under strict quarantine and GMAC conditions. The Feedtest laboratory requires additional handling and preparation areas Land area for research and experimental purposes
Plant Biotechnology Centre	A further enhancement in current capacity at DNRE/AV's Plant Biotechnology Centre is required in bioinformatics and high-throughput genotyping and plant gene expression profiling to offer a suite of platform technologies for plant genome analysis and plant functional genomics including gene expression arrays, DNA chips and high-throughput assays for plant gene function analysis. This would be of significant value to the collaborative partners and industry. Furthermore, a once-off capital investment for upgrade and relocation of NRE's Plant Biotechnology Centre, Agriculture Victoria at La Trobe University to purpose-build facilities at the Precinct of the La Trobe R & D Park and

Organization	Comment
	Technology Enterprise Centre, and for an extension of the available environmentally controlled- and containment glasshouse facilities jointly used by DNRE and La Trobe University will be required. This will further enhance collaborative interactions and partnerships with Academia and particularly with Industry (e.g. plant breeding companies, seed production companies, life sciences companies)
Pant Cell Biotechnology Centre	The PCBRC is looking for funding to aid in the purchase of a new high throughput sequencing mass spectrometer and a new automated nanobore HPLC system. These additions to our existing facilities would double our existing mass spectrometer sequencing capabilities. In addition, it is hoped to secure support for once senior researcher and a number of support staff. This will allow other research organizations and industries much broader access to both our facilities and our experience. Changes to the PCBRC's funding arrangements in 2000-04 will put pressure on instrument usage rates and access to facilities. Currently, 95% of the Centre's instrumentation and personnel time are committed to major collaborations.
Rutherglen Research Institute	The addition of mass spectroscopy to the institute would markedly improve our ability to define more accurately plant and soil processes in the rhizosphere.
State Chemistry Laboratory	There is an on-going requirement for high-quality, cost-effective research and analyses to support the government's "Naturally Victorian" initiative, sustainable agriculture programs, resource management and environment protection, and to increase market access for agricultural produce. As part of Agriculture Victoria, SCL is well placed to provide scientific input to all of these programs, however increased state investment would increase the laboratory's capacity to contribute. The potential returns from investing in new equipment technologies (robotics, ultra-trace analyses) are great. Funds are required to purchase very high cost ($500K) research and analytical instrumentation, particularly LC-MS and High Resolution GC-MS, which is needed both for research purposes (eg. functional foods) and complex analyses (eg. antibiotic residues in animal tissues). The current capital vote ($160K/yr) is grossly insufficient to allow the purchase of such high cost instrumentation or replace the capital base value ($3.1M), but it is important that the State Government have access to such technology, at the State Chemistry Laboratory.
Robotics and Mechatronics Research Laboratory	RMRL's current funding is mainly due to the extreme dedication and innovation of its research team, together with its success in gaining national competitive grants (such as ARC) and collaborating with industry. RMRL is unique in having the capability to conduct both fundamental research as well as generic/applied/industrial R&D. RMRL's trained graduates are extremely sought after within research institutions, academia, and industry. RMRL is a unique research laboratory which R&D services to many of Victoria's crucial industry especially the aerospace and commercial building and housing industries. Specific gaps in Victoria's STJ infrastructure relevant to RMRL include areas of non-contact sensing, prototyping equipment, optical measurement, autonomous systems research, multiarm robotics facility, and medical robotics. It must be emphasised that RMRL has the capacity to conduct the necessary research. In fact, the number of RMRL s research staff is growing rapidly in order to conduct major R&D programmes in collaboration with industry. However, the current space is limiting the capacity of RMRL. Therefore, additional space and building will also be required.
Royal Botanical Gardens and National Herbarium	The RBG urgently requires funding to increase it IT capacity to a level that is compatible with the current requirements in order to be in a position to deliver secure electronic services online. This increased capacity will enable the RBG to meet its public sector obligations, and develop and provide additional products and value-added services. In the context of integrating the RBG capabilities with the other scientific and cultural agencies, linking the RBG electronically with the Museum of Victoria, National Gallery of Victoria and the State Library of Victoria is highly desirable. A broadband network currently proposed for links to Federation Square could

Organization	Comment
	provide the necessary access and linkages for the RBG. The State Botanical collection is a wonderfully rich resource. A vast amount of information on the labels of the specimens is currently inaccessible to researchers and the public at large because the majority of the specimens have not been databased. There is a pressing need to database the entire collection so that this wealth of information associated with the collections can be made available electronically. Major funds are required to achieve this goal. The RBG has recently commenced this task with a substantial grant from the John T Reid Charitable Trust, but its completion will depend on funding grants for the Victorian government. ARCUE is expanding rapidly and capital is required to build permanent accommodation specifically for this institution. This accommodation is necessary to enable ARCUE to reach its potential. Additional accommodation is also required to house elements of the State Botanical Collection and the research staff.
The Centre for Early Human Development/Animal Gene Storage and Resource Centre of Australia	It is likely that expansion of the Centre's activities will soon exhaust the capacity of our present allocation in the Monash Institute of Reproduction building. To remain internationally competitive, the Centre will require access to certain classes of research infrastructure which are not currently readily available. The major classes are: ▪ High quality animal research and breeding facilities: Essential to the Centre's mission. Current facilities are inadequate, especially for the generation and maintenance of transgenic animals. The Centre has capability in cryopreservation which will play a major role in future management of transgenic stocks. ▪ Access to genomics and proteomics technology, including microarray, high throughput sequencing, protein microsequencing and two dimensional gel analysis, bioinformatics. Current access is on a piecemeal basis or is very expensive. We believe to facilitate access to such technology will require a centre on or near the Monash site. Modern facilities for cell biological research: We propose the development of an integrated facility bringing together key items of major equipment for modern cell biological research, including confocal microscopy, conventional light microscopy, image analysis, flow cytometry, laser scanning cytometry, laser capture microdissection, electron microscopy, optical tweezes. Although we currently have access to some of this equipment, some is outdated, and some is lacking altogether, and an integrated approach to management, maintenance and operation of such a facility would be highly advantageous. No such centre exists at present but it would be highly used by many groups within close proximity to the Monash campus.
World Health Organisation Collaborating Centre for Influenza	The Centre currently represents a unique potential benefit to Victoria and to Australia in the ability to deal with an influenza pandemic which could have devastating consequences worldwide. The Centre's ability to develop potential pandemic strains of influenza virus and reagents could greatly accelerate vaccine production in the event of a pandemic threat or pandemic (see Communicable Disease Intelligence, Technical Report Series 'A framework for and Australian Influenza Pandemic Plan' June 1999). However the Centre currently lacks a high containment laboratory facility which severely restricts its activities in this area and, for example, prevented it from working on the influenza A(H5N1) virus isolates responsible for the 'chicken flu' outbreak in Hong Kong in 1997. This deficiency has been noted in the above document and in draft state pandemic plans.

3 Capacity and capability building

Organization	Comment
Arthur Rylah Institute (ARI)	ARI is well placed to provide strategic ecological scientific input to many Victorian environmental programs. Increasing industry and community involvement in catchment management issues draws even programs. Increasing industry and community involvement in catchment management issues draws even greater requirement for access to interdependent and reliable ecological information. More complete geospatial (including GIS capabilities) information is needed on flora, fauna and freshwater biota to help in planning decisions across Victoria. This may require completion of current vegetation mapping (EVCs) and further modelling to predict fauna distributions. There is also a need to build dynamic models that predict changes in flora and fauna over time in response to climatic change or effects of management. A better understanding of ecological needs of flora, fauna and freshwater systems is essential to help resolve potential conflicts with benefits for biodiversity and Ecologically Sustainable Development.
Australian Neuroscience Society Incorporated	Neuroscience is at the threshold of major developments in the understanding of neurological diseases and in the application of biotechnology to the development of new therapeutics. Recent advances in molecular biology and neurochemistry, and information already flowing from sequencing of the human genome, are revolutionizing our understanding of the brain. It is now possible to elucidate the role of single molecules in the function of the nervous system and in neurological disorders, and to use this information to identify potential molecular targets for future therapies. Degenerative neurological disorders are common in Australia and are becoming increasingly prevalent in our aging society, and the financial and social burden to the Victorian community both for direct medical management and for community care are escalating. Victoria is in an excellent position to exploit the recent advances in the neurosciences. It is a research-intensive state, receiving the largest proportion of grant funding from the main national biomedical granting agency, the NHMRC (approximately 40%). The neurosciences make up the largest single subject for research funding from the NHMRC (approx 12.5% of total Project Grant funding), and in Victoria this proportion is higher than in other states. Victoria therefore has a higher concentration of expertise in the neurosciences, at clinical, scientific and technological levels, than any other state. In addition, Victoria is well placed to capitalise on its research capability in the neurosciences, by instigating and managing clinical trials for new therapeutics for neurological diseases, and by commercialising outcomes from its science. Biotechnology companies and pharmaceutical industry are well represented in Victoria and have already shown their willingness to become active partners in the development, testing, manufacture, marketing and sale of products based on local research. Recent changes to capital gains tax and other federal incentives are rapidly improving the climate for commercial development of intellectual property locally within Australia, and Victoria can expect to see a substantial expansion in this area. The combination of recent developments in our molecular understanding of the nervous system and our outstanding skill base in clinical and experimental neurosciences, together with the availability of local biotechnology partners, make Victoria uniquely well placed to benefit from fostering neuroscience research. The primary need now is to catalyse the interaction and integration of Victorian neuroscience research, so as to enable complementary skills that are fragmented between different research teams, and between research teams and industry partners, to be rapidly focussed into substantial, multidisciplinary collaborative efforts. To this end, we and others would support establishment of a Victorian Institute of Neuroscience. Such an institute should draw on the existing centres of excellence in neuroscience in Victoria, including the Centres for Neuroscience at Monash University and the University of Melbourne, the Howard Florey Institute and Mental Health Research Institute in Parkville, and the National Stroke Research Institute based at the Austin-Repatriation Medical Centre.

Organization	Comment
	A Victorian Institute of Neuroscience should not simply be yet another institute: it would not require its own building with suites of research laboratories, but would rely on existing laboratory facilities already in place around Victoria. Its primary role would be administrative, in fostering and facilitating interaction between existing nodes of excellence, supporting core facilities and provide a focus for industry collaborators and other activities with a commercial flavour. To this end its needs would be modest: suitably located offices with necessary administrative support staff, together with a realistic operating budget to achieve its main goal of adding value in Victoria to what is already major focus for Victorian research scientists. The roles of such an Institute could include: ▪ Supporting the provision of expensive core infrastructure facilities (such as primate colonies, transgenic animal facilities, functional MRI, PET scanning facilities, bioinformatics, IP/commercialisation-of-science expertise). Most of these need substantial financing to be set up and then stable recurrent support for core salaries. Many of these facilities are already in place as shared, multi-user resources run as consortia, but recurrent funding for core salaries needs to be assured to ensure they perform to high standards and are accessible to all stake-holders, and enable them to maximise their usefulness to the Victorian neuroscience community, and others. ▪ Facilitate collaborations between research groups with complementary skill, by providing responsive and rapid access to short-term funding requests arising from urgent new developments. The slow, annual turn-round of our national granting agencies, with delays of up to 22 months before funding is provided, make them completely inadequate to support cutting-edge work in internationally competitive fields, such as molecular neuroscience. ▪ Coordinating Victorian and/or national clinical trials in the neurosciences (similar to the Australian Stroke Trials Centre, a national coordination centre already based in Melbourne). Clinical trials funded by the private sector are of major economic value to the host state, and also offer major potential economic benefits in reducing community burdens of medical costs and social care. ▪ Provision of professional advice on intellectual property, provisional/full patents, potential venture capital partners, expansion of and gearing-up research programmes, and commercialisation of research outcomes in the neurosciences. Many tertiary education institutions, hospitals and research institutes have previously not been as strong in this area as current and future research activities will require us to be.
Centre for Animal Biotechnology	The Centre for Animal Biotechnology has no specific block funding allocated and is soley dependent on obtaining short-term competitive research grants to maintain its basic research infrastructure. Funding from the Australian meat and wool industries for basic research in veterinary science has disappeared in the last few years leaving a major gap in the veterinary research budget and resulting in may outstanding researchers leaving the field. Without this funding, the quality of the basic research cannot be maintained. The official establishment of a 'Large Animal Research Centre' by the government with a minimum 5 year budget allocation would provide a better structure for career development and would free-up time from writing grant applications to fostering increased collaborations with other research centers and industry partners.
Centre for Behavioural Research in Cancer	Non-university organisations such as CBRC which receive Federal and State research grants but do not receive commensurate infrastructure support funds, need support at least equal to the proportion universities would receive for success in the competitive grant arena.

Organization	Comment
Centre for Applied Hydrology	An emerging need in infrastructure and analysis is associated with remotely sensed data. NASA's new Terra satellite will be producing data of relevance to environmental issues and will be available at low cost but requires specific infrastructure to process the data.
Centre for Equine Virology	ILFR research capacity is high but currently under-funded and therefore under-utilised in relation to its full operating capability. This is principally due to rising costs, the need to meet full (not marginal) costs of the research and declining real availability of research funds together with an increasing tendency to 'partially fund' or require matching funds raised elsewhere. Specific gaps relevant to ILFR: - On farm factors affecting quality of products/consumer perception /confidence - GMO and the ethical and public awareness / prejudice issue - Equine industries
Centre for Land Protection Research	Specific gaps in Victoria's STI relevant to CLPR are in the areas of: - catchment hydrology - wetland hydrology - groundwater modelling - groundwater resource assessment - rural social science
CSIRO Atmospheric Research	The Victorian Government should consider investment in the application of weather and climatic forecasts. There would be economic benefits for Victorian industry, such as power generators and manufacturers, to incorporate accurate, timely and pertinent forecasts into their planning process. There appears to be a lack of appreciation of recently acquired improvements to forecasting ability of weather and climate, as well as of how this capacity can be translated into innovative improvements to industrial and commercial performance. The Queensland government has successfully implemented systems to enable agriculturists to better take advantage of climatic outlooks for activities including crop planning, stocking rates and fertiliser use. There is now opportunity for the Victorian Government to play a leadership role in developing outreach systems for industry to apply forecasts.
CSIRO Molecular Science	As far as the Advanced Composite Group is concerned, a big gap in Victoria's STI infrastructure is in the composite polymers area outside aerospace. The Group is presently attempting to fill this gap with a combination of industry and public sector input.
CSIRO Textile and Fibre Technology	Demand chain activities especially in the TCF Sector are critical to successful business practise. State based programs to encourage demand chain improvements based on innovation are essential. This division has found the supply chain program very useful in identifying innovation opportunities in the TCF&L Industry.
Department of Computer Science and Computer Engineering	We have argued at length elsewhere that current infrastructure, while leading to some excellent results, is severely restricted in terms of scale and funding. To overcome these limitations, we propose the establishment of a Victorian Software Engineering Institute. We further propose: (1) increased security in long-term funding; (2) increased funding for replacement purposes; and (3) the introduction of HECs liability for our graduate diplomas.
Fluid-dynamics Laboratory for Aeronautical and Industrial Research	FLAIR is a major provider of research and training in fluid mechanics and possibly the largest one in Victoria. Formed only 5 years ago, it has the potential of being the central focus of fluid mechanics for industry and government. There is at present no Victorian centre for assistance to industry in fluid dynamics, particularly in the manufacturing and automotive areas which are a major sector in Victoria. There is also the opportunity to capture a far greater share of the defence research spending in aerodynamics and hydrodynamics, which is currently undertaken in other states.
Food Science Australia	Require an understanding of the human and business processes aiding and holding back commercialization of innovative technologies in the food manufacturing industry, so that barriers can be overcome by appropriate government programs. Maximization of benefits from a national approach to STI infrastructure in food related areas, and improved mechanisms to provide for the needs of the States (mechanisms involving other States, beyond the Victorian/Commonwealth approach embodied in Food Science Australia).
Geological Survey of Victoria	Industry has concerns about the work of the GSV being effectively supported by the NRE. If significant global minerals companies are to be attracted to Victoria,

Organization	Comment
	there must be a vibrant and strong GSV. While Victoria has many competent research institutions, what is missing is the review of projects in the context of the State's interests - this is a gap the GSV can fill. The GSV should also pursue the development of computer-based models to permit the 3D visualisation of data in its own right. Also the testing of theoretical geological models is a fundamental research activity far beyond the resources of private companies - this is another area were the GSV could and should be active,
High Performance Computing and Communications Centre	Victoria has traditionally been the centre for industry in Australia, and in particular, the centre of the automotive industry and its key suppliers. HPCCC is a key part of the engineering design for overseas automotive companies and suppliers, but has not played a major part in Australia. The Australian subsidiaries of overseas companies have tended to make limited use of facilities provided in their headquarters, but the usefulness has been limited by slow networks, and the problems of visualisation of large amounts of data. There is an opportunity in this industry to build an integrated design capability, as has been done at the University of Stuttgart for Daimler-Chrysler, Porche, and others. Similar opportunities exist for other industries, e.g. oil exploration, ship building, electricity market analysis, etc.
ILID Partnership	Our main suggestion is probably what you are doing this survey for. It would be greatly beneficial time and cost wise if a directory/network of available STI resources in Victoria was made available, either in hard copy form or via the Internet. Another aspect that would be helpful would be a directory of state and national funding schemes and organisations. For someone who wishes to see his/her invention become real and marketable, and is seeking advice and information on where to begin, searching for such material is currently a hit-and-miss operation. A single source that lists all innovation schemes and organisations, briefly describes each one, and provides contact details would be extremely helpful.
Institute for Horticultural Development	Specific gaps in STI infrastructure capability relevant to Institute of Horticultural Development; ▪ diagnostic science plant diseases- succession planning issue a classical diagnostician required for the commercial diagnostic service ▪ industry specialist ornamentals - no expertise currently available to service demands of the cut flower and nursing industries ▪ Non English Speaking Background and horticultural scientists- no expertise currently available to service needs of Victorian vegetable industry
Kraft Foods	Over the last several years, the Victorian government has taken significant steps to improve the linkage of the STI infrastructure to industry, to focus the resources on fewer and bigger opportunities and to create fewer centers of more significant critical mass. This has also seen development of expertise in some areas which are important to the food industry but which were previously under funded, eg, process engineering and sensory consumer science. We would be keen to see continued moves in these general areas
Laboratory for Turbulence Research in Aerospace and Combustion	A significant proportion of aerospace activity in Australia is located in Victoria. In Victoria, aerospace activity can be found in the private and commercial aviation and air transport sector, the airforce, DSTO, and in education. At present this sector is lacking an appropriate level of support in research and development, and in the supply of people with a high level of training in these skills. Organisations like the LTRA&C are presently able to only partially fill the gap that exists in this support. If the present gap is to be filled, and if this gap is to remained filled, greater support from the LTRA&C, for example, to this sector is required. Since its inception six years ago, the LTRA&C through its staff has been involved in the training and development of around 10 honours level undergraduate projects per year, had 10 graduate projects and numerous post-doctoral and visiting research fellows. During this time, the laboratory has been successful in obtaining over $1million in grants and research contacts.

Organization	Comment
	These facts point not only to the quality of the work done in the laboratory, but the demand for this type of work in Victoria. One example of this is the recent grant of $450,000 for work on hybrid rocket motors which has the to potential to lead to a number of exciting new developments . While the laboratory receives funding to undertake work on a project by project basis, expansion of the laboratory's activities to meet the future needs of, for example an expanding Victorian Aerospace Industry, will require additional targeted funding. The need for more funding is made even more crucial when it is considered that the LTRA&C is presently operating at maximum capacity in respect of both its experimental infrastructure and in its 'bricks and mortor'.
Melbourne Water Corporation	The situation is generally satisfactory from the technical aspect in that most significant issues in the water industry are being addressed at national, state and regional levels. However it is arguable that gaps in capability (knowledge) exist or deficiencies need to be expedited in a number of areas some of which involve national and interstate collaboration. For example:· - Development of the National Water Quality Management Strategy (NWQMS), which began in 1991, is still to be finalised. The main parties to the strategy are the Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) and the Australian and New Zealand Environment and Conservation Council (ANZECC) with input from the National Health and Medical Research Council (NHMRC) where appropriate. Some aspects of the relationship between drinking water quality, enhanced water quality standards and public health benefits· - Automated systems for process monitoring and control of sewerage processes and systems - The health of rivers and the relationship with environmental flows and general water resource allocation· - Relationship between standards imposed by the environmental regulator and environmental benefits and costs in meeting them - Health aspects and public acceptance of recycled treated sewage effluent and stabilised biosolids
Mutation Research Centre	Provide for salaries and costs, which are impossible to obtain from the granting bodies. This is true "Infrastructure" and includes secretaries, business managers, and laboratory managers. Patent, legal and library costs are in this category and are crucial for commercialization and scientific advances. Germany has a system where one can apply to the state for patent fees, a topic of vital interest. It is widely recognised that grants awarded to research centres vary widely from year to year and while current infrastructure costs, quite rightly and logically, relate to competitive grants, there should be an averaging system, so that when a centre has a bad year, the funding is not reduced as much as it would be, if the rule was strictly enforced. This then allows the Centre to recover with new grants in the future.
Ovens Research Station	Perceived problems include; - diagnostic science plant diseases- succession planning issue a classical diagnostician required for the commercial diagnostic service - industry specialist ornamentals- no expertise currently available to service demands of the cut flower and nursing industries - Non English Speaking Background and horticultural scientists- no expertise currently available to service needs of Victorian vegetable industry
Palaeo-Environments Group	Our group would hope that the Victorian State Government would continue to support the geosciences in Victoria by maintaining the government research and development roles etc in the State Geological Survey, for the petroleum and resources sector and the provision of data for industry exploration and development, university research and development for the future growth of the state's economy. The excellent quality of the recent past is a testament to the commitment of recent state governments to the development of the state.
VicHealth Centre for Tobacco Control	Non-university organisations such as VCTC which receive Federal and State research grants but do not receive commensurate infrastructure support funds, need support at least equal to the proportion universities would receive for success in the competitive grant arena. - Capacity for analytic testing of tobacco

Organization	Comment
	products
VicRoads	VicRoads has identified a series of gaps in knowledge within its four areas of business: ▪ Significant opportunities exist in the development of intelligent transport systems to improve traffic flow, reduce accidents and managed demand; ▪ Developmnet of netwrok level performance measures to imporve confidence in the prediction of long-term road pavement performance; ▪ Development of new bridge testing methods to measure load endurance etc. ▪ Use of advanced composite materials for road and bridge strengthening. Additional funding for work on these areas would be effectively used.
Water Studies Centre	The WSC has an existing high quality and well-developed base in the area of water quality and well-developed base in the area of water quality research. Victoria has a growing need for the generation of new knowledge in water quality to assist in better managing the State's water resources. STI infrastructure funds would enable the WSC to consolidate and then expand its existing research and information exchange capabilities. This would then provide the base from which to target a range of key water quality management projects that would contribute to improving Victoria's sustainable development program.
St Vincent's Institute of Medical Research	Successive Governments in Victoria have recognised the importance and role of the independent research institutes. These institutions, because of their independent status, are not eligible to receive infrastructure support from DETYA that is normally allocated against peer-reviewed funding. A number of national studies have shown that there is a real infrastructure cost of 70 cents for each dollar of direct funding (i.e. 42% of total research expenditure is infrastructure). The State Government presently attempts to allocate to each institute a sum to support infrastructure to the level of 20% of peer-reviewed funds. While this level of support is important to individual institutes, it still does not cover the real cost of infrastructure, which must then be met from other sources. *The Victorian Government should increases infrastructure support to independent health and medical research institutes, initially to a level of 35% of peer-reviewed funds, and encourages the Federal Government to provide matching levels of support.*

4 Investment in people

Organization	Comment
Australian Institute of Physics	Are concerned that physicists have lost jobs through closure of research and development laboratories at BHP (1999) and the former CRA now Rio Tinto (1998). Furthermore, concern also exists with regard to trends in society and science and technology policy issues meaning that there are not enough opportunities for physicists to contribute to the future of Australian industry. Views expressed about the role of R&D by the heads of some of the largest Australian companies at the National Innovation Summit were depressing and short sighted
Australian Institute of Radiography	Due to the severe shortage of Radiographers and Radiation Therapists in Australian and Victoria, workforce planning surveys are required and this Institute requested State Government funding for this project more than two years ago wit no result. It is beyond this Association's financial resources to fund such a project
Microanalytical Research Centre (MARC)	The most serious gap in Victoria's STI infrastructure is in the area of training in basic research. The present lack of suitable career structure for young researchers in the university system (and the great stress in the university system produced by the federal government's cuts to funding) have put the prospects for future innovators in doubt.
Museum Victoria	Invertebrate Survey: Museum of Victoria is a centre for collection-based research. There are several groups of animals of economic, health or ecological sustainability value for which there are no active taxonomists. The State Government would have nation wide competitive advantages if some of these positions were staffed at the Museum. Crustecea: Real gaps in knowledge of the fauna of Victoria which will be overcome only by greater commitment to research and information generation and retrieval. Entomology: From a digital technology point of view, the acquisition of a digital scanning electron microscope would greatly enhance the ability to the researchers and public programs. DOE involvement could involve many schools throughout Victoria though a web based interaction. More funding for non-university or industry based research. Museums undertake research on our natural heritage for our and future generations and this long term responsibility of the State is often overlooked.
Mutation Research Centre	Strategic Salaries. In the early 1980's, good projects and laboratories were well funded. Viewing from the same seat in 1999/2000, it is clear that 1/3 to 1/2 of valuable projects and workers are not funded. This is underlined by the fact that the Ludwig lodged 11 NHMRC grants without success and LaTrobe University were only awarded 1 from 23 applications. Whilst the NHMRC is doubling its budget over the next years, these figures suggest the impact will be minimal. Thus, the State needs to account for the fact that funding key individuals and projects may be terminated and provide for "special grants", perhaps funding projects with scores within 0.5 of NHMRC cutoff and which are argued as strategic. Our fundraising features the "special scientist" category where funds can be used in these categories. Students Support. Many good PhD students miss out on funding and several of these approached us before they found their funding was not awarded. Students are the life blood of any centre and are often responsible for the lion's share of any progress and keep established staff on their toes with questions. Not only are stipends (very small) needed, but student awards do not include laboratory expenses. Thus, there are two components. The first could be looked after by offering funds to fund a certain number who do not get Federal grants. Also, infrastructure grants could include laboratory costs. Again these items are key in our fundraising drive. - The less scientists' have to do with fundraising and its associated pressures, the more productive they will be.
PROBE Analytical	In the last year two staff members were retrenched and have no full-time members of staff aged under 30 to whom we can pass on our knowledge and expertise for the future.

Organization	Comment
	PROBE plays a pre-eminent role in problem solving for the chemical and allied industries in Victoria. It has managed to achieve this by hiring staff of the highest calibre. PROBE was established and funded by ICI (Australia) in more prosperous times. We have pioneered the use of Nuclear Magnetic Resonance as a major industrial problem solving tool in Victoria. We are a recognised centre of expertise in chromatographic analyses. Our progress as leading innovators in both areas will be drastically impeded unless we receive urgent assistance with our capital expansion program. Assistance with funding to purchase a new 500MHz NMR Spectrometer and Electrospray LC-MS equipment is our immediate requirement. Approximately $1,200,000 would be needed to restore PROBE to its former position of the leading independent, industrial consulting laboratory in Australia. Note: One of my major concerns as PROBE manager is the lack of opportunity we are providing young Victorian Science graduates. If we had funding to assist with capital expansion, we would be in a better position to hire young scientists. Their natural enthusiasm and recently acquired skills would be a shot in the arm for laboratory staff here not to mention the knowledge we could pass on to Victoria's future top guns.
Research Centre for High Energy Physics	For the Research Centre for High Energy Physics, the critical gap in Victoria's STI infrastructure pertains to suitably qualified people: (1) industrial liaison personnel, (2) individuals to give briefings to industry and academia on state of the art techniques, (3) support personnel to assist academic and industry joint applications for funding.
Rofin Australia Pty Ltd	The company reports some difficulty in finding people with both strong research and teamwork capabilities and is concerned with capabilities in Australia of optics generally.
Rio Tinto	There are no specific gaps in the Victorian infrastructure that effect Rio Tinto. The global nature of the company, and the ability to work with institutions worldwide mean that Rio Tinto is less dependent on local facilities than most companies. However, the technological strength of the local universities, and of the CSIRO, is important. The existence of these institutions in Victoria is an important factor behind Rio Tinto maintaining Victoria as the centre of its internal R&D.

5 Cooperation, and Collaboration and Networking

Organization	Comment
Aerospace Technologies of Australia [ASTA Components]	The logistical infrastructure gaps paramount to ASTA's successful operation are explained below:- ▪ Infrastructure logistics for International Research and Development cooperation with USA companies is lacking. This requires government-to-government cooperation at a high level to formulate the requisite agreements. ▪ There is currently poor access for industry to defence related programs. ▪ There is currently no indigenous product/program in Australia which brings aerospace entities together and provides a catalyst for cooperation.
Australian Meteorological and Oceanographic Society	In the past applications have been made to Government for assistance in the holding of International meetings in Melbourne. As a society, we have been unsuccessful in our application and therefore are not encouraged to bring such projects to the State. Whilst we are willing to communicate our research to the community, this takes time and effort and it is a cost we cannot carry
Composites Instiute of Australia	As compared with other State's Universities, Victorian Universities have been sadly lacking in commercial focus as far as the composites industry is concerned, with only the Wackett Aerospace Centre involved as RMIT is a CIA member. As for other STI gaps, the composites industry in the northern hemisphere is currently undergoing major technological shifts after a prolonged period of relatively static manufacturing processes. For the local industry to remain competitive it is imperative that these technologies be made available to local industry practitioners. CIA endeavours to meet this need by bringing out leading experts in the relevant fields to conduct seminars in the major local cities. The consulting fees asked by these people, together with the associated travel costs which we must meet, limit the extent to which we can conduct these events, even though we charge a registration fee for the attendees.
Nufarm Ltd	Australia is well positioned to segregate GM and conventional crops and Nugrain aims to service both sectors. With the controversy over GM crops seemingly at its height, it may not have been the best time for Nufarm to enter the fray. Leadership from government would assists Australians to learn from the lessons from Europe and the US, as Nufarm believes that the long term prospects for the technology are good.

6 Support for Commercialisation

Organization	Comment
Australian Biotechnology Association Ltd	Despite Victoria's strong scientific community and research institutes related to biotechnology when successful biotech ventures in Victoria are compared with the scientific infrastructure the outcomes are somewhat limited. This is especially so when the benchmark for comparison is Canada which in many respects has the same kinds of problems as we experience in Australia - large land mass, small population, small markets and limited venture capital.
	We believe that there is a pent-up demand by investors to identify and invest in short term and strategic industries in the biotech area. These include the industry manufacturing drugs and therapeutics and also devices. It perhaps comes as no surprise to realise that CSL and Cochlear are the two 'darlings' of the stock market in the biotech area at the present time.
	It has been pointed out on many occasions, but it is worth noting again that Victoria and other states need to be able to fund and support the pre-commercial developments that are necessary to get fledgling business on its feet. In many cases this requires long term finance at favourable rates and some form of mentoring with large successful companies, particularly those that can manage brands successfully on the international market. For example, Bonlac has a strong record in developing and positioning new bio products in the domestic and international markets.
	The Victorian government could give support to the development of suitable pre-commercial large-scale testing facilities, or at least expedite a database for developing a public network so that the availability of these resources is well known and also to link with the other states so that there is a strategic Australia-wide network that people can use to develop any products in the stage between the laboratory and full scale production.
	The second area that the Government needs to address is the one of support financial and business wise for investors. In other words, to provide a link into the business world so that the serendipity in creating business partnerships is maintained and allows fresh blood in.
Australian Diagnostic Manufacturers Association	We hear all the time that our science is great and our commercialisation capabilities are lacking. The latter is simply not true.
	Personal experience indicates that the commercialisation of a great deal of 'technology' is not passed to the professionals but attempted by the scientists of research institutes eg Universities set their own commercialisation groups eg 'Xtech' and staff them from within or with technology qualified people - insufficient experienced commercial, general management, sale & marketing people appear to be employed.
Australian Ingredient Centre	Traditional R&D centres in the agrindustry focus exclusively on the development of a product or process, rather than coming-up with a total package which includes commercialisation.
	The AIC is one of the few organizations in the State which attempts to service clients and stakeholders by simultaneously conducting scientific and market research.
Genetics Australia Co-operative Ltd	It would be helpful if there were a strategy for bringing together research and commercial interests to capitalise on existing strengths in biotechnology. A strategy to develop agricultural applications with a focus on research likely to improve agriculture's competitive position. The willingness of institutional research organizations to work collaboratively with other institutions and commercial partners on focussed projects is a particular consideration.
Glaxo Wellcome Australia Ltd	The primary skill gaps in the current medical and health science base are the protection of intellectual property, capability for full pharmaceutical development, lack of venture capital and infrastructure to commercialize Australian discoveries.
	What Australia lacks is an entrepreneurial culture in exploiting the science base. We need scientists who understand business and can support and develop science from laboratory to market. This contrasts with USA where many in venture capital business have originally come from academia.
	Intellectual Property (IP) IP skills should be taught in all science degrees. Wealth is now based on knowledge and scientists should be taught how to protect and exploit this knowledge through use of IP. There is a view that success in the future for

Organization	Comment
	companies will depend on their ability to protect the IP they create. Failure of Australian scientists to protect their IP has resulted in loss of economic benefits to the Australian economy and loss of financial rewards for the people who made the discoveries. The Australian discoveries mentioned previously have resulted in large sales and profits for foreign companies. The future of Australian science will depend on its ability to reduce its dependence on Government funding. This could be achieved through the commercialisation of IP. Income could be earned through selling or licensing of patents to companies which would make up front payments and /or royalty payments to the individuals or institutions who made the discoveries. Capability for Pharmaceutical Development The knowledge of drug development is relatively low in Australia and the country lacks the capability to fully develop a new molecule into a medicine ie to "take a molecule to market". The expertise exists in Australian institutions and industry to achieve parts of drug development ie conducting clinical research, preparing regulatory submissions, pharmaceutical development and commercial manufacture but there are substantial gaps. Australia does not yet have the capability for automated combinatorial chemical synthesis and screening of molecules for physicochemical properties, pharmacological and toxicological development and scale up of chemical synthesis to commercial primary production of active therapeutic agents. Multi-disciplinary Approach to R&D Another important capability is the need for project management in the drug discovery and development. The multi-disciplinary approach in drug development requires project management skills. Infrastructure and Venture Capital to Commercialise Australian R&D The skill to recognise the value of technology and innovation in biomedical sciences is lacking in Australia. The venture capital needs to be well directed. We need venture capitalists who can add management value and strategic skills as well as money. This is the mix of skills that have been so successful in the US. Although there are a number of small biotechnology companies in Australia, there are inadequate venture capital funds and infrastructure to commercialise Australian discoveries. Also there is a lack of understanding of the process for the development of a new therapeutic agent and the costs associated with the commercialisation of a new medicine. Too often Australian scientists and small start up R&D companies reject the advances of multinational pharmaceutical companies because of the desire to keep the discovery in Australia. This is a naive notion because the high costs of drug development, gaps in development capability and because the return on investment requires the successful commercialisation in global markets. The Australian pharmaceutical market accounts for 1-2% of the value of the global market. Australian scientists can realise value for their intellectual property through licensing deals with large multinational companies. Potential royalties to individuals and institutions from global sales are likely to be substantial. Recommendation to Commercialise Australian R&D Strategies to achieve economic benefits - training of scientists in intellectual property - strategic analysis of drug development in Australia to identify skill gaps - multi-disciplinary and collaborative approach to R&D and commercialisation - focus on new technologies - world class education system and research facilities which will attract and retain world class scientists in Australia. Funding and Incentives - funding for projects that have significant commercial potential - environment conducive to pharmaceutical R&D, manufacturing and export activities - increase the amount of funding for pharmaceutical industry - reduce corporate taxation to 31% as planned and restore the 150% R&D tax concession - Government should reconsider the implementation of draconian pricing policies for reimbursed medicines Collaborations between Industry and Science - collaboration between industry and medical research scientists - Government funding of research should be linked to industry investment. - Technology Parks should be encouraged industry should provide scholarships, work experience and training positions for tertiary level students

Organization	Comment
	and academics
Invetech Operations Pty Ltd	In general, a healthy innovation system requires a lively venture capital sector. Given that venture capital is now a global business, for so long as our capital gains tax regime lags so far behind the US in its treatment of corporate venture capital, the smart money will continue to head for NASDAQ, and the smart ideas and people will follow it.
Water and Eliza Hall Institute of Medical Research	Issues identified include ▪ Funding to establish and operate 'incubator' stage prior to 'investment-ready' ▪ Management of 'Investment-ready' marketing *I* securing investors / entrepreneurial skilled people ▪ Costs of maintaining international patents, and management of Intellectual Property ▪ Lack of co-ordination of Government activities ▪ Impoverishment of funding for clinical research
St Vincent's Institute of Medical Research	There is now much greater focus on the proper management of intellectual property that emerges from the higher education research sector, including the independent medical research institutes. This management includes the protection of any intellectual property by taking out appropriate patents etc. It has been recognised by all commentators that there exists a major funding gap in this process, between taking out a provisional patent and the registration of a full patent internationally (and the recruitment of a commercial partner and access to additional funding). Most researchers and their administering institutions do not have the finance available to support this crucial activity (up to $100,000). These funds can not be supported from research grants. As a result, many potential developments are not protected, and hence are lost from further development and national advantage. *The Victorian State Government should develop procedures to assist researchers to finance the gap in protection of intellectual property, between the initial registration of provisional patents and the recruitment of a commercial partner and taking out full international patent protection.*

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Annexes

Annex 1: Letter requesting information for inclusion in the STI Information Base.

A copy of the letter, with supporting material, informing people and organizations about the STI Review is provided below.

[Howard Partners]

Date

«Title» «FirstName» «LastName»
«JobTitle»
«Department»
«Company»
«BusinessStreet»
«BusinessStreet2»
«BusinessStreet3»
«BusinessCity» «BusinessState» «BusinessPostalCode»

Dear «Title» «LastName»

Survey of Victoria's Science, Technology and Innovation Infrastructure

Howard Partners has been asked by the Victorian Department of State and Regional Development to undertake a survey of Victoria's science, technology and innovation (STI) infrastructure. The survey is part of the Government's initiative to strengthen Victoria's innovation base by providing new funding of $310 million for investment in science and technology based projects initiated by industry, research organizations, or government agencies.

The purpose of the survey is to provide:

- Information on innovation resources available for use by industry and research organizations;
- An information base for Australian and global businesses seeking the best locations for investment in high technology industries; and,
- Information to drive efficient use of infrastructure.

Businesses in Victoria may receive assistance under the Government's initiative in the form of improved access to science and technology infrastructure and from the expansion of cross sectoral research networks or 'innovation platforms'.

My purpose in writing to you at this stage is to alert you to the existence of the survey and to ask you to provide some basic information about «Company» and how it relates to Victoria's wider science, technology and innovation infrastructure. A copy of the press statement from the Minister for State and Regional Development announcing the survey is also attached.

An important aspect of the survey is to provide data on relationships that bring together infrastructure such as where cross-sectoral research or collaboration occurs, and where there is commercial interaction. This information will complement information on location, ownership and use of research and development infrastructure.

Attached is an initial survey *Request for Information* that seeks some broad details about the operations and activities of «Company». Following receipt of the information requested, we may contact you again, via follow-up interview and email, to obtain further detail about matters such as:

- Specific detail on capacity and usage rates
- Access regimes and user profiles
- Capital and running costs
- Effective life cycles
- Replacement schedules for key equipment and buildings
- Relationships with other research organizations (in Australia and overseas)
- Arrangements for collaboration with industry.

We would appreciate early advice of the name and contact details of a person in «Company» who can act as a liaison person.

Please do not hesitate to contact me if you would like to know more about the survey. I can be contacted in our office in Canberra on 02 6247 0200 and by email at vicset@howardpartners.com.au.

I look forward to working with you on this important project designed to significantly enhance Victoria's science and technology base.

Yours sincerely

John Howard
Director

ATTACHMENT

Howard Partners

Survey of Victoria's Science, Technology and Innovation Infrastructure.

Request for Information about «Company»

Howard Partners would appreciate receiving some information about «Company» for the purpose of establishing a core information base about science, technology and innovation resources in Victoria.

We are contacting «Company» because it has a listing in the 1999 Technology Directory of Australia.

Following receipt of the information requested, we may make further contact to obtain more specific details about aspects of your company for inclusion in the information base.

The information sought at this stage, *in summary form*, is as follows:

1. Contact details for the person who will liaise with us for the purposes of the survey (name, phone, fax and email address)
2. Generally available current information about the science, technology and innovation capability at «Company», including -
    - Ownership and location
    - The number of professional research staff
    - Qualifications, skills and experience of research team leaders
    - Descriptions of any installations of research instrumentation and their estimated replacement costs
    - A brief description of the distinctive capability of «Company»
    - The main fields of research covered (preferably using the standard Australian *field of research* codes)
    - The size of the capital and operating budgets.
3. Information on the level and sources of funding sources, including recent and current
    - Government grants
    - Assistance under the R&D Tax Concession
    - Other.
4. The main university and public sector research collaborators - with an indication of the research fields in which this collaboration takes place
5. Information relating to collaboration between business and their external research base ie public and private research providers – including
    - Commercial ventures
    - Sponsorships
    - Endowments
6. A brief description of how «Company» contributes to Victoria's STI infrastructure capacity (e.g. through direct research outcomes or indirectly through research training etc)
7. Available information about capacity, usage rates, access regimes and user profiles

8. Effective life cycles and replacement schedules for key equipment and buildings
9. Relationships and affiliations with other research organizations (in Australia and overseas)
10. A brief account of any specific gaps in Victoria's STI infrastructure capability relevant to «Company» that should be considered for investment by the State Government.

If any of this information is already available in a report or submission, please forward a copy of the document(s) to the Survey Team.

We would welcome any additional comments or suggestions you might have to make about the role that the Victorian Government might play in improving the STI infrastructure and on impediments to carrying out effective research and innovation in Victoria.

We would be grateful of you could return this information, either in hard copy or Word 97/2000 by *Friday 21 January 2000* to:

John Howard
Science, Technology and Innovation Survey Team
Department of State and Regional Development
Level 13, 55 Collins Street
MELBOURNE. VIC 3000

Email: vicset@howardpartners.com.au

If you have a difficulty in meeting this timeframe, please let the Survey Team know when it might be possible to forward it. The Team can be contacted in Melbourne on 03 9651 9337 or in Canberra on 02 6247 0200.

FOR PRESS

FROM THE MINISTER FOR STATE AND REGIONAL DEVELOPMENT

FIRST EVER SURVEY OF VICTORIA'S INNOVATION INFRASTRUCTURE

A landmark Statewide survey of Victoria's science and research infrastructure will commence before Christmas, the Minister for State and Regional Development, John Brumby, announced today. "Investment in innovation is fundamental to building new industries and creating jobs of the future. The Victorian Government is committed to building the State's research and development capabilities," Mr Brumby said.

"This survey is crucial to making the right decisions about State investment in science, technology and innovation infrastructure. The survey will also assist industries to assess their own research and development needs for the new millennium," Mr Brumby said.

The survey is part of a Government initiative to strengthen Victoria's innovation base by providing new funding of $310 million for science and technology based projects initiated by industry, research organisations, or government agencies. The survey will provide essential information including:

- current location, ownership, and use of research and development infrastructure
- capacity, usage rates, access regimes and user profiles for research and development assets
- capital and running cost of research and development assets
- effective life cycles and replacement schedules for key equipment and buildings.

Howard Partners will also provide data on relationships that bring together infrastructure such as where cross-sectoral research or collaboration occurs, or where there is commercial interaction.

The survey will produce:

- information on innovation resources available for use by industry and research organisations
- an information base for Australian and global businesses seeking the best locations for investment in high technology industries
- information to drive efficient use of infrastructure.

"The survey will help us to ensure funds go where they are most needed to develop new industries and boost growth," the Minister said. "Assessment of infrastructure for the biotechnology sector will be an early priority of the survey."

"The survey will examine research infrastructure in regional Victoria as well as in Melbourne," Mr Brumby said. "I encourage all private sector, university, and government research organisations across Victoria to participate."

Howard Partners has been contracted by the Department of State and Regional Development to undertake the survey with completion timetabled for April 2000. For further information, Howard Partners may be contacted on telephone 02 6247 0200.

Annex 2: Research centres contacted for inclusion in the STI Data base

The following list was used for initial contact to develop the STI Database. All Centres were included in a mail-out in December 1999.

Centre	Location	Response
Victorian Institute of Animal Science	Attwood	Yes
Biotechnology Research Centre	Bendigo	
Institute of Drug Technology Australia Ltd	Boronia	Yes
Applied Biotechnologies Pty Ltd	Brooklyn	
Australia & New Zealand Environmental Mutagen Society Inc	Bundoora	
Centre for Conservation Genetics	Bundoora	
Plant Science & Biotechnology Unit	Bundoora	
Royal Women's Hospital	Carlton	Yes
Centre for Behavioural Research in Cancer	Carlton South	Yes
Bioelectronics Group	Caulfield East	
Water Studies Centre	Caulfield East	Yes
Centre for Environmental Science	Churchill	
Australian Society for Reproductive Biology	Clayton	
Centre for Agricultural Biotechnology	Clayton	
Centre for Biomedical Engineering	Clayton	
Centre for Bioprocess Technology	Clayton	
Centre for Human Bioethics	Clayton	
CSIRO Minerals	Clayton	
Electron Microscopy Services Unit	Clayton	
Institute of Reproduction & Development	Clayton	Yes
Monash University Centre for Biomedical Engineering	Clayton	
Montech Pty Ltd	Clayton	
Neuropsychology Research Unit	Clayton	
Neurosciences Group	Clayton	
Prince Henry's Institute of Medical Research	Clayton	Yes
Clean TeQ Pty Ltd	Dandenong	
CSIRO Animal Health	East Geelong	
National Centre in HIV Virology Research	Fairfield	
Australian Federation for Medical & Biological Engineering	Fitzroy	
Mutation Research Centre	Fitzroy	Yes
St Vincent's Institute of Medical Research	Fitzroy	Yes
Australian Biotechnology Association Ltd	Gardenvale	
Australian Animal Health Laboratory	Geelong	
Centre for Applied Colloid & Biocolloid Science	Hawthorn	
CRC for International Food Manufacture & Packaging Science	Hawthorn	Yes
ICI Australia Operation Pty Ltd	Hawthorn	
Swinburne Limited	Hawthorn	
The Austin Research Institute	Heidelberg	Yes
AMRAD Corporation Limited	Kew	Yes
Nufarm Limited	Laverton North	
Biota Holdings Limited	Melbourne	Yes
Centre for Bioprocessing & Food Technology	Melbourne	
Key Centre for Applied & Nutritional Toxicology, RMIT	Melbourne	
Lipoprotein / Atherosclerosis Unit	Melbourne	
The Australian Society for Microbiology Inc	Melbourne	
The Baker Medical Research Institute	Melbourne	Yes
The Walter & Eliza Hall Institute of Medical Research	Melbourne	Yes
The Arthritis Foundation of Victoria Centre for Rheumatic Diseases	Moonee Ponds	Yes
Australian Biomedical Corporation Ltd	Mount Waverely	
Invetech Ltd	Mount Waverley	Yes
Trace Scientific Ltd	Noble Park	Yes
Bio Nova International Pty Ltd	North Melbourne	
Australasian Society for Immunology Inc	Parkville	Yes

Centre	Location	Response
Centre for Animal Biotechnology	Parkville	Yes
Centre for Equine Virology	Parkville	Yes
Centre for Hormone Research	Parkville	Yes
CRC for Cellular Growth Factors	Parkville	Yes
CRC for Industrial Plant Biopolymers	Parkville	
CSIRO Division of Molecular Science	Parkville	Yes
CSL Limited	Parkville	
Glycoscience Group	Parkville	
Howard Florey Institute of Experimental Physiology & Medicine	Parkville	Yes
Mental Health Research Institute of Victoria Inc	Parkville	Yes
Micro-Analytical Research Centre	Parkville	Yes
Plant Cell Biology Research Centre	Parkville	Yes
The Biomolecular Research Institute Limited	Parkville	Yes
The Murdoch Institute	Parkville	
Unimelb Limited	Parkville	
World Health Organisation Collaborating Centre for Influenza	Parkville	Yes
Van Cleef/Roet Centre for Nervous Diseases	Prahran	
CRC for Discovery of Genes for Common Human Diseases	Richmond	Yes
Bioproperties (Australia) Pty Ltd	Ringwood	
Soltec Research Pty Ltd	Rowville	
Institute for Integrated Agricultural Development	Rutherglen	
Consulchem Pty Ltd	Scoresby	
Rancoo Limited	South Yarra	
Victorian Institute of Forensic Medicine	Southbank	
Biological & Biotechnology Group	Waurn Ponds	
Knowledge Acquisition & Processing Group	Waurn Ponds	
Molecular Science Group	Waurn Ponds	
Australian Starter Culture Research Centre Limited	Werribee	
State Chemistry Laboratory	Werribee	Yes

Source of Organizations Listing: *The Australian Technology Directory*

Annex 3: Companies contacted for inclusion in the STI Data base

The following list was used for initial contact to develop the STI Database. All Companies were included in a mail-out in January 1999.

Company	Location	Response
Aberfoyle Limited	Melbourne	
Alpha Sensors	Melbourne	
Australian Mineral Industries Research Association Limited	Melbourne	Yes
BHP Petroleum International Pty Ltd	Melbourne	Yes
Bisan Limited	Melbourne	
Cody Opals (Australia) Pty Ltd	Melbourne	
Ericsson Australia Pty Ltd	Melbourne	
Geo2 Limited	Melbourne	
Pacific Dunlop Limited	Melbourne	
Pratt Industries Pty Ltd	Melbourne	
Rio Tinto	Melbourne	
Shell Development (Australia) Proprietary Limited	Melbourne	
The Broken Hill Proprietary Company Limited	Melbourne	Yes
The Shell Company of Australia Limited	Melbourne	
Granitgard Pty Ltd	East Melbourne	
Associated Pulp & Paper Mills Ltd	Melbourne	
BCS Focus Pty Ltd	Melbourne	
Beam International Limited	Melbourne	
Beku Environmental Products Ltd		
Biota Holdings Limited	Melbourne	Yes
Bonlac Foods Limited	Melbourne	
Cargill Australia Limited	Melbourne	
Computer Power Group Limited	Melbourne	
EMF Consultants (Vic) Pty Ltd	Melbourne	
Jord Engineers Pty Ltd	Melbourne	
Pasminco Limited	Melbourne	
Strathayr Turf Systems	Melb	
Western Geophysical Company	Melbourne	
Freestream	Footscray	
Huntsman Chemical Company Australia Limited	Footscray West	
National Forge Limited	Footscray West	
Warren & Brown Technologies Pty Ltd	Maidstone	
Albright & Wilson (Australia) Limited	Yarrawville	
Dow Chemical (Australia) Limited	Altona	
United Surface Technologies Pty Ltd	Altona	
Adept Robotics Pty Ltd	Brooklyn	
Applied Biotechnologies Pty Ltd	Brooklyn	
Bunge (Australia) Pty Ltd	Altona North	
Sirius Biotechnology Limited	Altona North	
Captec Pty Ltd	Laverton North	
Nufarm Limited	Laverton North	Yes
Agrifood Technology	Werribee	
Abon Engineering Pty Ltd	Airport West	
Newtronics Pty Ltd	Tullamarine	
Bio Nova International Pty Ltd	North Melbourne	
SPC Limited	Nth Melbourne	
CSL Limited	Parkville	
Australian Computing & Communications Institute Ltd	Carlton	
ITworks Consulting Pty. Ltd.	Carlton	
KE Software Pty Ltd	Carlton	
Southern Dental Industries Limited	Bayswater	
Virtual Photonics Pty Ltd	Carlton	
Icom (Australia) Pty Ltd	Brunswick	
Townley Drop Forge Pty Ltd	Brunswick East	
Electrotek Rewind Pty Ltd	Coburg	
Monochromatic Engineering Pty Ltd	Fawkner	
Andrew Australia Pty Ltd	Campbellfield	
Ford Motor Company of Australia Limited	Campbellfield	
Florigene Pty Ltd	Collingwood	
Oliver J Nilsen (Aust) Pty Ltd	Collingwood	
The ILID Partnership	Collingwood	Yes
AMCOR Limited	Abbotsford	
Compumedics Pty Ltd	Abbotsford	
John Holland Group Pty Ltd	Abbotsford	
Resource Industry Associates Pty Ltd	North Fitzroy	
Comgroup Preston	Preston	
Howe & Co Pty Ltd	Preston	

Company	Location	Response
Hytech Scales Pty Ltd	Preston	
Davies Shephard Pty Ltd	Keon Park	
Ciba Specialty Chemical	Thomastown	
Stainless Associates Pty Ltd	Thomastown	
Sutton Tools Pty Ltd	Thomastown	
Webb Conveyor Company of Australia Pty Ltd	Thomastown	
International Mirai Technologies Pty Ltd	Ivanhoe	
Logix Pty. Ltd.	Ivanhoe	
QNA International Pty Ltd	East Ivanhoe	Yes
DAPS Australia Pty Ltd	Heidelberg West	
Aerospace Technical Training Australia Pty Ltd	Bundoora	
Diamond Systems Pty Ltd	Hurstbridge	
AMRAD Corporation Limited	Kew	
Softronics Pty Ltd	Kew	
Drummond International Pty Ltd	Bulleen	
Mayall Australia Pty Ltd	Richmond	
Siemens Limited	Richmond	
The Preston Group Pty Ltd	Richmond	
Cuming & Associates Pty Ltd	Hawthorn	
Enersonics Pty Ltd	Hawthorn	
Interact Plastic Services Pty Ltd	Hawthorn	
Quest Software Australia Pty Ltd	Hawthorn	
Tupperware Australia Pty Ltd	Hawthorn	
Contrec Systems Pty Ltd	Hawthorn East	
Automotive Electronic Specialists Pty Ltd	Camberwell	
McFarlane Laboratories Pty Ltd	Surrey Hills	
Carter Holt Harvey Tissue Australia Limited	Box Hill	
Microbeam Services - a Division of Aberbrook Pty Ltd	Box Hill	
Whittle Programming Pty Ltd	Box Hill	
Bayly Design Pty Ltd	Blackburn	
Ecotech Pty Ltd	Blackburn	
Gainsborough Hardware Industries Limited	Blackburn	
Geocomp Systems Pty Ltd	Blackburn	
Hewlett-Packard Australia Limited	Blackburn	
Pascom Technologies Pty Ltd	Mitcham	
ARRB Transport Research Pty Ltd	Vermont South	
Teletech Pty Ltd	Vermont	Yes
Bioproperties (Australia) Pty Ltd	Ringwood	
CMG Electric Motors Pty Ltd	Ringwood	
Open Software Associates Limited	Ringwood	
SGE International Pty Ltd	Ringwood	
Dewalt Power Tool Company P/L	Croydon	
SRL Plasma Limited	North Croydon	
Moldflow International Pty Ltd	Kilsyth	
Datacraft Technologies Pty Ltd	Mooroolbark	
Dynamic Structures Pty Ltd	Mooroolbark	Yes
Sigma (Pharmaceuticals) Pty Ltd	Croydon	
Arlec Australia Limited	Lilydale	
Pyropanel Developments Pty Ltd	Lilydale	
Circadian Technologies Limited	Toorak	
Argenta Australia Pty Ltd	Armadale	
Common Sense Computing Pty Ltd	East Malvern	
Berry Design Pty Ltd	Glen Iris	
Pains-Wessex (Australia) Pty Ltd	Glen Iris	
KEL Aerospace Pty Ltd	Ashburton	
Invetech Operations Pty Ltd	Mount Waverley	Yes
Optiscan Pty Ltd	Mt Waverly	
Vision Instruments Limited	Mount Waverely	
Castec Australia Pty Ltd	Glenwaverley	
Hitek Ltd	Glen Waverley	
NAK Equipment Pty Ltd	Glen Waverley	
NEC Australia Pty Ltd	Glenwaverley	
IXLA Limited	East Burwood	
CMC Research Pty Ltd	Wantirna South	
Dynavac Engineering Pty Ltd	Wantirna South	
Signal Processing Associates Pty Ltd	Wantirna	
ANCA Pty Ltd	Bayswater North	
Automated Fusion Technology Pty Ltd	Bayswater	
Mark Sensing Australia Pty Ltd	Bayswater	
Stewart Plastics Pty Ltd	Bayswater	
Wavin Hall Pty Ltd	Bayswater	
AZ Tooling Pty Ltd	Boronia	
Glaxo Australia Pty Ltd	Boronia	Yes
Glaxo Wellcome Australia Ltd	Boronia	Yes

Company	Location	Response
Industrial Process Controls Ltd.	Boronia	
Comlabs Systems & Designs Pty Ltd	Caulfield	
Lochard Pty Ltd	Caulfield North	
EDL Australia Pty Ltd	Carnegie	
Car & Aircraft Design Pty Ltd	Bentleigh East	
Applied Measurement Australia Pty Ltd	Oakleigh	
Davey Products Pty Ltd	Huntingdale	
Ogden Industries Pty Ltd	Oakleigh	
Recoil Pty	Oakleigh	
Solomon Corrosion Control Services Pty Ltd	Oakleigh South	
Carpenter Advanced Ceramics Pty Ltd	Clayton	
Drager Australia Pty Ltd	Notting Hill	
Ferntree Computer Corporation Limited	Clayton	
Fibernet Division of Australian AMP Pty Ltd	Notting Hill	
LSC Lighting Systems Pty Ltd	Clayton	
Unidrive Pty Ltd	Clayton	
Vision Products Pty Ltd	Clayton	
Chiron Technologies Pty Ltd	Clayton South	Yes
Luke & Singer Pty Ltd	Clayton South	
Moss Products Pty Ltd	Clayton	
Varian Australia Pty Ltd	Clayton South	
Amskan Ltd	Mulgrave	Yes
BHP Research	Mulgrave	Yes
Customloc Pty Ltd	Mulgrave	
Dorian Industries Pty Ltd	Mulgrave	
Martin Communications Pty Ltd	Mulgrave	
McVan Instruments Pty Ltd	Mulgrave	
Neville Crocker Australia Pty Ltd	Mulgrave	Yes
Kwik Draw Engineering Pty Ltd	Springvale	
Rofin Australia Pty Ltd	Dingley	Yes
Inverwood Holdings Pty Ltd	Scoresby	
BASF Australia Ltd	Noble Park	
Ceramic Fuel Cells Ltd	Noble Park	
Structured Data Systems Pty Ltd	Noble Park	
Trace Scientific Ltd	Noble Park	Yes
Clean TeQ Pty Ltd	Dandenong	Yes
Gasresearch Australia Pty Ltd	Dandenong	
GBC Scientific Equipment Pty Ltd	Dandenong	
Port-O-Kiln (Aust) Pty Ltd	Dandenong	
Agriculture Victoria Services Pty Ltd	South Eastern	
Data Electronics (Aust) Pty Ltd	Rowville	
Kingfisher International Pty Ltd	Rowville	Yes
Consulchem Pty Ltd	Scoresby	
Motorola Australia Pty Ltd	Scoresby	
Unique Micro Design Pty Ltd	Scoresby	
UVS Ultra Violet Pty Ltd	Scoresby	
Webster Computer Systems Pty Ltd	Scoresby	
Javac Pty Ltd	Knoxfield	
Robotron Pty Ltd	St Kilda	
Rosetta Laboratories Pty Ltd	St Kilda	
Adacel Technologies Limited	Brighton	
Amphenol Australia Ltd	Moorabbin	
Amtron Valve Monitoring Device Pty Ltd	Moorabbin	
Lewis Australia Pty Ltd	Moorabbin	
Marand Precision Engineering Pty Ltd	Moorabbin	
Ronstan International Pty Ltd	Sandringham	
Aim Product Design Pty Ltd	Cheltenham	
Ausdel Pty Ltd	Cheltenham	
Australian Challenge (Operations) Pty Ltd	Cheltenham	
Cyco System Pty Ltd	Cheltenham	
Gibson Chemical Industries Ltd	Cheltenham	
Laser Lab International Pty Limited	Cheltenham	
Novatech Controls (Aust) Pty Ltd	Cheltenham	
Paper Technology International Limited	Cheltenham	
Bytecraft Pty Ltd	Mordialloc	
Labtam Australia Pty Ltd	Braeside	
Power Tech Systems Pty Ltd	Mordialloc	
Mindata Australia Pty Ltd	Seaford	
Trio Communications 2000 Pty Ltd	Seaford	
Nylex Corporation Lmited	Frankston	
Autoscan Systems Pty Ltd	Ormond	
Data General Australia Pty Ltd	South Melbourne	
Electronic Digital Innovations Pty Ltd	South Melbourne	
Lurgi (Australia) Pty Ltd	South Melbourne	

Company	Location	Response
Microsystem Controls Pty Ltd	South Melbourne	
Redflex Limited	South Melbourne	
Smiths' Industries Australia Pty Limited	South Melbourne	
Westinghouse Signals Australia Ltd	South Melbourne	
Aerospace Technologies of Australia Ltd	Port Melbourne	Yes
General Motors-Holden's Automotive Ltd	Port Melbourne	
Gunnersens Pty Ltd	Port Melbourne	
Hawker De Havilland Victoria Ltd	Port Melbourne	
Intertek Testing Services (Australia) Pty Ltd	Port Melbourne	Yes
Kraft Foods Limited	Port Melbourne	Yes
Scientific Services Laboratory	Port Melbourne	
Vipac Engineers & Scientists Limited	Port Melbourne	
Brake Technologies Pty Ltd	Geelong North	
Gearing Dynamics Pty Ltd	Geelong North	
Jones & Jones Engineering Design Pty Ltd	Geelong	
TJS Systems	Geelong	
Test Technology Pty Ltd	Ocean Grove	
John Valves Pty Ltd	Ballarat	
Ballarat Goldfields NL	Ballarat	
C E Bartlett Pty Ltd	Wendouree	
Automation Engineering Pty Ltd	Kyneton	
Butler Solar Systems Pty Ltd	Castlemaine	
Mildura Co-operative Fruit Company Ltd	Mildura	
Pauls (Vic) Ltd	Bendigo	
Empire Rubber (Australia) Pty Ltd	Bendigo	
Australian Oxytrol Systems Pty Ltd	Eaglehawk	
Ceramic Oxide Fabricators Pty Ltd	Eaglehawk	
Ardmona Foods Limited	Mooroopna	
Digital Signal Processing Systems Pty Ltd	Mooroopna	
Environmental Products Amalgamated Pty Ltd	Shepparton	
Uncle Ben's of Australia Pty Ltd	Wodonga	
DRW Water Management Pty Ltd	Montrose	
Air Fence Safety Systems Pty Ltd	Emerald	
Pollutec Operations Pty Ltd	Mornington	

Source: *Technology Directory of Australia*

Annex 4: Associations contacted for inclusion in the STI Data base

Association/Society	Location	Response
Australian Society for Limnology Inc	Abbotsford	Yes
Genetics Australia Co-operative Ltd	Bacchus marsh	Yes
Institute of Instrumentation and Control Australia Inc	Balwyn	
Society of Manufacturing Engineers	Balwyn	
Field Naturalists' Club of Victoria	Blackburn	Yes
Australian Biotechnology Association Ltd	Brighton	Yes
Australian Earthquake Engineering Society	Bundoora	
Epilepsy Foundation of Victoria	Camberwell	Yes
Australian Institute of Agricultural Science	Carlton	
Optometrists Association Australia	Carlton	Yes
Metrology Society of Australia	Clayton	Yes
Endocrine Society of Australia	Clayton	
Australian Society for Reproductive Biology	Clayton	
Australian Physiology and Pharmacology Society	Clayton	
Australian Institute of Radiography	Collingwood	Yes
Australian Society of Soil Science Inc	Creswick	
Composites Institute of Australia Inc	Croydon	Yes
Australian Diagnostic Manufacturers Association	East ivanhoe	Yes
Haemophilia Foundation Australia	East malvern	
Australian Medical and Export Services Group	Glen waverley	
Australian Equity Association	Hawthorn	
Australian Industrial Research Group	Kew	Yes
Australian Institute of Food Science and Technology	Keysborough	
Australian Society of Horticultural Science	Knoxfield mc	
Australian Chemical Specialties Manufacturers Association	Melbourne	Yes
Intellectual Property Society of Australia and New Zealand Inc	Melbourne	
Surface Coatings Association Australia Inc	Melbourne	
Australian Society for Microbiology Inc	Melbourne	
Australian Meteorological and Oceanographic Society	Melbourne	Yes
Australian Manufacturers' Patents, Industrial Designs, Copyright and	Melbourne	
Water Services Association of Australia	Melbourne	
Plastics and Chemicals Industries Association Inc	Melbourne	
Victorian Association of Forest Industries	Melbourne	
Speech Pathology Australia	Melbourne	Yes
Australian Society for Operations Research	Melbourne	
Australian Institute of Petroleum Ltd	Melbourne	
Australian Council of Building Design Professions Ltd	Melbourne	Yes
Australian Mathematical Sciences Council	Melbourne	
Australian Dairy Products Federation	Melbourne	Yes
Australian Minerals and Energy Environment Foundation	Melbourne	
Electrical Development Association of Victoria	Mount waverley	
Society of Automotive Engineers	North melbourne	
Australian Institute of Physics	North melbourne	Yes
Australian Engineering and Building Industries Research Association Inc	Parkville	
Australian Neuroscience Society Incorporated	Parkville	Yes
Spine Society of Australia	Parkville	Yes
Arthritis Foundation of Victoria Centre for Rheumatic Diseases	Parkville	Yes
Australian Wool Processors Council	South Melbourne	
Cement and Concrete Association of Australia	South yarra	
Institute of Hospital Engineering, Australia	Thornbury	Yes
Dairy Industry Association of Australia Inc	Werribee	

Annex 5: Expenditure on Research and Development in STI Field of Research and Output categories

In this Part of the Report we have provided information about the structure of the Victorian STI resource base in terms of expenditure classified by fields of research (an indicator of research effort) and socio-economic objective (an indicator of research results)

Data obtained in a special return from the Australian Bureau of Statistics for this Study indicates that, in 1996-97, $2.3 billion was invested in research and development in what may be considered to have a "science and technology" orientation. Information is presented in this section in terms of fields of research and socio-economic objective.

- **Fields of Research**

Expenditure classified by field of research seeks to identify research effort and provides a proxy indicator of research and development capability.

The expenditure in specific fields and by organization is indicated in Table 5.

Table 32: Expenditure on Research and Development by Field of Research and Sector

Field Of Research	Common wealth Government		State Government		Higher Education		Business		Private Non Profit		Total Expenditure	
	$'000	%	$'000	%	$'000	%	$'000	%	$'000	%	$'000	%
Mathematical Sciences	4,970.5	1.7	20.7	0.0	14,296.7	4.1	4,889.3	0.3	0.0	0.0	24,177.2	1.0
Physical Sciences	17,954.3	6.1	0.0	0.0	15,145.3	4.3	4,349.7	0.3	0.0	0.0	37,449.2	1.6
Chemical Sciences	32,140.2	10.8	350.0	0.2	23,351.0	6.7	57,390.8	4.0	391.2	0.4	113,623.1	4.9
Earth Sciences	27,199.9	9.2	2,303.1	1.4	12,932.3	3.7	9,315.9	0.7	68.6	0.1	51,819.8	2.2
Information, Computer And Communication Technologies	20,323.6	6.9	1,107.7	0.7	29,040.9	8.3	413,521.8	29.0	71.3	0.1	464,065.2	20.0
Applied Sciences And Technologies	93,418.2	31.5	2,917.5	1.8	24,424.5	7.0	468,817.9	32.9	8.0	0.0	589,586.1	25.4
General Engineering	51,050.8	17.2	1,809.8	1.1	35,054.8	10.0	371,798.9	26.1	329.0	0.4	460,043.3	19.8
Biological Sciences	24,480.9	8.3	17,532.0	10.9	46,817.1	13.4	13,076.9	0.9	17,044.9	19.2	118,951.7	5.1
Agricultural Sciences	23,006.2	7.8	91,329.8	56.8	22,465.7	6.4	19,066.3	1.3	27.5	0.0	155,895.5	6.7
Medical & Health Sciences	2,068.3	0.7	43,390.1	27.0	127,049.5	36.2	63,036.8	4.4	70,734.6	79.8	306,279.4	13.2
	296,612.9	100.0	160,760.7	100.0	350,577.7	100.0	1,425,264.1	100.0	88,675.2	100.0	2,321,890.6	100.0

The data indicate that total expenditure on research and development is concentrated in the fields of information, communications technologies, applied science and technologies, general engineering and medical and health sciences. These fields account for 78 percent of research and development expenditure

State Government expenditure is concentrated in the agricultural sciences, biological sciences and the medical and health sciences. These three broad fields make up 95 percent of the State Government's research and development effort. It reflects the commitment to the primary production and public health sectors – particularly clinical research and disease prevention. Commonwealth expenditure is concentrated in the areas of applied sciences and technologies, general engineering and chemical sciences. The main Commonwealth organizations represented in Victoria are the CSIRO, Bureau of Meteorology, and the DSTO.

Higher education research is heavily concentrated in the medical and health sciences, biological sciences and the chemical sciences. There is also a high level of commitment in the engineering, applied science and computer, communication and communication technologies. This reflects Victoria's strong medical research base in the university sector and strength of the three technology universities.

The business sector invests heavily in applied science and technologies, information, computing and communication and general engineering.

The private non-profit sector makes a substantial contribution to the area of the health, medical and biological sciences.

In terms of the overall research effort, the business sector has the highest overall commitment to R&D. The focus of business sector research and development effort is concentrated in the chemical sciences, information, computers and communication, applied sciences and general engineering. This is indicated in Table 6, which indicates that the business sector undertakes 61.4 percent of the research effort.

Table 33: Proportion of R&D Expenditure by Sector and Field of Research

Field Of Research	Common wealth Government	State Government	Higher Education	Business	Private Non Profit	Total Expenditure
Mathematical Sciences	20.6	0.1	59.1	20.2	0.0	100.0
Physical Sciences	47.9	0.0	40.4	11.6	0.0	100.0
Chemical Sciences	28.3	0.3	20.6	50.5	0.3	100.0
Earth Sciences	52.5	4.4	25.0	18.0	0.1	100.0
Information, Computer And Communication Technologies	4.4	0.2	6.3	89.1	0.0	100.0
Applied Sciences And Technologies	15.8	0.5	4.1	79.5	0.0	100.0
General Engineering	11.1	0.4	7.6	80.8	0.1	100.0
Biological Sciences	20.6	14.7	39.4	11.0	14.3	100.0
Agricultural Sciences	14.8	58.6	14.4	12.2	0.0	100.0
Medical & Health Sciences	0.7	14.2	41.5	20.6	23.1	100.0
	12.8	6.9	15.1	61.4	3.8	100.0

Research in other areas indicates a strong public sector focus in the physical, earth and agricultural sciences.

The higher education sector also invests heavily in the physical, biological, medical and health sciences. Much of this investment is at the basic, or discovery, level of scientific endeavour. The distribution of expenditure within the university sector is of interest –

Table 34: R&D Expenditure at Victorian Universities

	Melbourne	Monash	Latrobe	Deakin	RMIT	Swin-burne	Ballarat	VUT	Total
	$'000	$'000	$'000	$'000	$'000	$'000	$'000	$'000	$'000
Mathematical Sciences	7,747	3,496	1,652	387	271	173	127	444	14,297
Physical Sciences	9,408	2,082	1,110	0	1,375	132	0	1,039	15,145
Chemical Sciences	9,827	8,297	2,162	539	599	623	0	1,305	23,351
Earth Sciences	5,040	4,277	1,875	682	821	0	175	63	12,932
Information, Computer & Communication Technologies	10,431	8,448	2,581	836	3,444	690	532	2,078	29,041
Applied Sciences And Technologies	6,988	3,549	550	0	6,006	3,804	17	3,512	24,425
General Engineering	13,653	13,686	361	567	3,796	389	157	2,447	35,055
Biological Sciences	24,080	9,344	9,189	539	1,427	110	280	1,848	46,817
Agricultural Sciences	16,795	3,134	1,577	240	261	24	315	120	22,466
Medical And Health Sciences	71,640	29,204	13,949	4,528	4,408	1,187	716	1,419	127,050
	175,609	85,516	35,005	8,318	22,407	7,131	2,319	14,274	350,578

The data point to a concentration of research in the Universities of Melbourne and Monash, which account for approximately three quarters of the expenditure. The important role of Melbourne University in supporting the medical and health sciences is also apparent. However, the research effort is also significant at RMIT University and Victoria University.

The university research effort is undertaken in the faculties as well as a number of specialist centres and institutes with some independence from the faculty. Detailed information on expenditure by field of research for Victoria is set out in Appendix 1.

On a national basis, Victoria accounts for just fewer than 30 percent of public sector R&D. This is indicated in Table 8.

Table 35: Proportion of Australian R&D Expenditure in Victoria

	Australia	Victoria	Proportion
	$'000	$'000	$
Mathematical Sciences	73,431	19,288	32.7
Physical Sciences	158,513	33,100	19.2
Chemical Sciences	136,880	55,841	30.5
Earth Sciences	291,700	42,435	16.2
Information, Computer & Communication Technologies	262,514	50,472	26.7
Applied Sciences And Technologies	213,362	120,760	38.1
General Engineering	195,734	87,915	31.1
Biological Sciences	345,033	88,830	23.6
Agricultural Sciences	230,112	136,802	28.1
Medical And Health Sciences	352,704	172,508	42.0
	2,259,983	779,137	28.8

Further details of research fields are set out in Appendix 3.

- **Expenditure by socio-economic objective**

The socio-economic classification seeks to identify research and development effort by categories of "end-user". It is essentially a "purpose" classification.

Summary information concerning expenditure by socio-economic objective for 1996-97 is provided in Table 9. Information is also provided on the proportion of expenditure sourced in each sector. Detailed information is provided in Appendix 8.

Table 36: Expenditure on Research and Development by Socio Economic Objective and Sector

Socio economic objective	Commonwealth Government		State Government		Higher Education		Business		Private Non-Profit		Total Of Expenditure	
	$'000	%	$'000	%	$'000	%	$'000	%	$'000	%	$'000	%
Defence	76,418.9	24.6	0.0	0.0	1,281.0	0.3	53,823.0	4.5	0.0	0.0	131,522.9	5.9
Plant and animal production	30,919.0	9.9	84,803.2	50.9	19,057.0	3.9	12,911.0	1.1	18.0	0.0	147,708.2	6.6
Mineral resources excl. Energy	18,885.7	6.1	4.1	0.0	4,478.7	0.9	14,951.0	1.3	0.0	0.0	38,319.6	1.7
Energy resources and supply	11,838.9	3.8	85.3	0.1	4,659.1	1.0	27,897.0	2.3	101.7	0.1	44,582.1	2.0
Manufacturing	93,768.1	30.1	0.0	0.0	22,815.4	4.7	790,502.0	66.4	1,367.3	1.4	908,452.7	40.4
Construction	16,845.9	5.4	1,489.2	0.9	12,818.4	2.6	13,022.0	1.1	28.6	0.0	44,204.1	2.0
Transport	3,430.2	1.1	1,186.0	0.7	4,369.7	0.9	29,365.0	2.5	4.8	0.0	38,355.7	1.7
Information and communication services	3,387.0	1.1	738.4	0.4	10,791.5	2.2	179,225.0	15.0	60.8	0.1	194,202.7	8.6
Commercial services	692.0	0.2	474.3	0.3	3,541.0	0.7	18,118.0	1.5	201.8	0.2	21,782.2	1.0
Health	6,389.7	2.1	47,985.3	28.8	120,721.8	24.9	32,902.0	2.8	74,987.0	78.6	282,985.9	12.6
Education and training	0.0	0.0	1,541.5	0.9	30,486.0	6.3	642.0	0.1	7,074.0	7.4	39,743.6	1.8

Socio economic objective	Commonwealth Government		State Government		Higher Education		Business		Private Non-Profit		Total Of Expenditure	
	$'000	%	$'000	%	$'000	%	$'000	%	$'000	%	$'000	%
Social development and community services	4,448.3	1.4	2,477.9	1.5	9,413.0	1.9	1,977.0	0.2	299.6	0.3	18,615.8	0.8
Environmental knowledge	24,965.3	8.0	17,179.2	10.3	17,109.6	3.5	3,625.0	0.3	802.6	0.8	63,681.6	2.8
Environmental aspects of economic development	10,622.7	3.4	889.3	0.5	5,103.0	1.1	1,117.0	0.1	9.5	0.0	17,741.5	0.8
Environmental management and other aspects	3.8	0.0	4,010.2	2.4	3,774.2	0.8	4,315.0	0.4	14.3	0.0	12,117.4	0.5
Natural sciences, technologies and engineering	546.8	0.2	3,093.3	1.9	128,393.5	26.5	6,621.0	0.6	10,115.6	10.6	148,770.2	6.6
Social sciences and humanities	36.0	0.0	541.9	0.3	65,900.8	13.6	0.0	0.0	74.0	0.1	66,552.7	3.0
Economic framework	7,819.8	2.5	85.0	0.1	20,423.3	4.2	58.0	0.0	186.7	0.2	28,572.8	1.3
	311,018.2	100.0	166,584.0	100.0	485,137.1	100.0	1,191,071.0	100.0	95,346.2	100.0	2,247,911.5	100.0

The data indicate that Victoria's total research effort is heavily concentrated in the manufacturing sector with 40.4 percent of expenditure occurring in this area. This is consistent with the data on fields of research that point to the commitment to applied sciences and technologies and engineering.

There is also a high concentration of research and development effort in the health services, plant and animal production, information and communication services and defence. The data also indicate a major commitment to research and development in the natural sciences, technologies and engineering.

Within the overall spread on investment in research and development, there are some significant differences in commitment between sectors. This is shown in the Table 10.

Table 37: Proportion of R&D Expenditure by Sector and Socio Economic Objective

Socio economic objective	Commonwealth Government %	State Government %	Higher Education %	Business %	Private Non-Profit %	Total Of Expenditure %
Defence	58.1	0.0	1.0	40.9	0.0	100.0
Plant and animal production	20.9	57.4	12.9	8.7	0.0	100.0
Mineral resources excl. Energy	49.3	0.0	11.7	39.0	0.0	100.0
Energy resources and supply	26.6	0.2	10.5	62.6	0.2	100.0
Manufacturing	10.3	0.0	2.5	87.0	0.2	100.0
Construction	38.1	3.4	29.0	29.5	0.1	100.0
Transport	8.9	3.1	11.4	76.6	0.0	100.0
Information and communication services	1.7	0.4	5.6	92.3	0.0	100.0
Commercial services	3.0	2.1	15.5	79.4	0.9	100.0
Health	2.3	17.0	42.7	11.6	26.5	100.0
Education and training	0.0	3.9	76.7	1.6	17.8	100.0
Social development and community services	23.9	13.3	50.6	10.6	1.6	100.0
Environmental knowledge	39.2	27.0	26.9	5.7	1.3	100.0
Environmental aspects of economic development	59.9	5.0	28.8	6.3	0.1	100.0
Environmental management and other aspects	0.0	33.1	31.1	35.6	0.1	100.0

Socio economic objective	Commonwealth Government %	State Government %	Higher Education %	Business %	Private Non-Profit %	Total Of Expenditure %
Natural sciences, technologies and engineering	0.4	2.1	86.3	4.5	6.8	100.0
Social sciences and humanities	0.1	0.8	99.0	0.0	0.1	100.0
Economic framework	27.4	0.3	71.5	0.2	0.7	100.0
	13.8	7.4	21.6	53.0	4.2	100.0

The data confirm the high commitment of the State to research and development relating to plant and animal production, health and environmental knowledge. The Commonwealth has a high commitment to defence, mineral resources and environmental aspects of economic development. Industry focus is on energy, manufacturing, transport, information and communication and commercial services.

A number of socio-economic areas indicate substantial levels of investment by each sector - government, higher education and industry. This occurs particularly in plant and animal production, energy, manufacturing (although no input from State Government), health and the environment. There is little government investment in the information and communication services.

Some of industry based research effort is formalized through mechanisms such as cooperative research centres, but in many cases collaboration takes place with government involvement or assistance.

Annex 6: Relationship Between Research Effort, Research Outputs And Outcomes in STI Areas

In an endeavour to obtain an indication of the relationship between research effort (reflected in fields of research) and research outputs and outcomes (reflected in socio-economic objective), we sought to "map" the fields of research with the socio-economic objective with which it is associated. Our intention was to provide some insight into the relationship between nature of research being undertaken (capability) and the users of that research and a proxy indicator of the level of innovation in each sector.

While the basic components for mapping the relationship between research effort and outputs is available through the Australian Bureau of Statistics, the information is far too aggregated to enable capabilities to be mapped. Moreover, the Bureau does not keep data on relative capability levels – important for assessing the potential opportunities for strategic investment.

A survey instrument was distributed electronically to 400 organizations that had been identified in the STI Information base. Research capability was ranked in a range 1 to 5, with five equating with world-class capability.

Unfortunately, there were only 53 responses. This makes statistically significant conclusions difficult. The data does, however, assist in providing an indication about how capability is being utilized in industry. This information is provided in Table 11 with more detailed information provided in subsequent sections of the Report and in Appendix 5.

Table 38: Research Capabilities and End User - Summary

Socio-economic Objective	No of FOR Classes Identified	No of Capabilities Identified	Total Capability Level	Average Capability – *Capability Index*	Number of Orgs Responded
Health	37	73	196	2.7	12
Defence	11	30	120	2.7	3
Construction	14	24	80	3.3	4
Manufacturing	85	253	879	3.5	23
Animal Production and Primary Products	16	20	29	1.5	3
Commercial Services	25	52	185	3.6	6
Economic Framework	12	12	44	3.7	2
Education	41	62	198	3.2	9
Energy Resources	3	5	16	3.2	1
Energy Supply	13	13	57	4.4	2
Environment	22	45	141	3.1	4
Environmental Aspects of Economic Development	14	14	51	3.6	5
Environmental Management Other Aspects	17	37	74	2.0	2
Information and Communication Services	28	107	389	3.6	8
Mineral Resources	1	1	3	3.0	1
Natural Sciences	110	152	502	3.3	15
Transport	8	15	32	2.1	5
Plant Production and Primary Products	15	21	69	3.3	4

In Table 11 *the Number of FOR Classes Identified* refers to the individual research fields that were identified by at least one respondent organization in which they had a capability. The *Number of Capabilities* refers to the number of times respondents identified their organization as having a capability in that field. The *Total Capability Level* is the sum of capabilities with rankings applied (from 1 to 5). Dividing the total capabilities by the number of capabilities identified derives the average capability.

The average capability level gives an indication of the overall level of research capability and innovative effort in each particular output/outcome category. This can be referred to as an *Innovation Capability Index.* The survey results imply that Victoria has a high level of research and innovative capability in energy supply, economic framework, commercial services, the environment, manufacturing and information and communication services.

The level of capability is probably understated in the health area due to the low response rate from the medical research institutes. This is a pity as it is understood that Victoria has a very high level of capability in health related research and development.