Developing Long-term Strategies for Science and Technology in Australia: Outcomes of the Study Matching Science and Technology to Future Needs 2010

1996

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outcomes of the study: matching science and technology to future needs 2010

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Letter of Transmittal

The Hon. Peter McGauran MP
Minister for Science and Technology
Parliament House
CANBERRA ACT 2600

Dear Minister

We have the honour of submitting to you a report: *Developing long-term strategies for science and technology in Australia -- outcomes of the study Matching Science and Technology to Future Needs: 2010.*

In this study, ASTEC applied 'foresight' processes to come to a better understanding of the forces shaping the long-term future. 'Foresight' allowed us to address many difficult issues Australia faces in managing the rapid pace of scientific and technological change. In accordance with the terms of reference, ASTEC is providing an information base to assist government and industry make better informed decisions about the development and application of science and technology.

A feature of this study has been the catalytic role taken by ASTEC, with an emphasis on process, involvement and wide consultation with industry and the research and education communities. Other important features included Partnership studies which provided opportunities for groups of organisations to look at future priorities in their sector.

This outcomes report identifies a number of Priority Actions for government. We would of course welcome the opportunity to expand on these recommendations. Additional information supporting this report is to be released separately in the form of a findings report.

This study is a first for Australia and has demonstrated the value of 'foresight' in policy formulation and decision-making. I believe it can be used fruitfully to help match our science, technology and engineering to emerging needs and opportunities into the 21st Century.

Yours sincerely

D G Williams
Chairman
May 1996

L D Beazley	E Heij	C Mountford
D I Blesing	R D Johnston	J D Vines
W J Caelli	J de Laeter	
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Terms of reference

Given the Government's objective to improve Australia's long-term economic competitiveness and our social and environmental well-being, by maximising the contribution from science and technology; and, noting the importance of adopting a forward looking approach:

A. Examine possible national and global changes to the year 2010, specifically:
   i) Australia's key future needs and opportunities which rely on, or could be significantly affected by, scientific developments and the application of technology; and
   ii) potential mismatches in the supply of and demand for science and technology in Australia.

B. In addressing A:
   i) engage in an extensive consultative process in accord with international best practice in foresight designed to match science and technology to national objectives;
   ii) encourage the collective identification of important themes for future science and technology planning in both the public and private sectors; and
   iii) increase awareness and understanding of the value and methods of future-oriented analysis.

C. Provide an information base which can assist government and industry to make better informed decisions on the development and application of science and technology.

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Mr John Vines: Partnership: Young People's Dreams and Expectations for Australia in 2010 and the Role of Science and Technology

Dr Don Williams: Partnership: Science and Technology Directions in the Maritime Industry, Key Issue Roundtables: The Need to Capture Opportunities from Globalisation; and, The Need for Innovation and Entrepreneurship.

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Chairman's Foreword

The links between science and research outcomes and socio-economic progress are complex and uncertain. However, science and technology (S&T) 'foresight' offers promise as a means to help ensure Australian science, engineering and technology contribute to national objectives, including through the identification of priority areas in research and development for both economic and social benefit.

In this study, ASTEC has applied foresight processes to evaluate the S&T needs of Australia to 2010. Foresight is an iterative learning process which, in ASTEC's view, should become an integral part of Australia's S&T planning. The output must be regarded as the *first* iteration – an exploration of foresight.

Benefits from this study fall under two basic headings: *process*, from the testing of foresight in S&T planning in government and industry; and *product*, from a strategically based set of tactical S&T policy recommendations, primarily for the Commonwealth government.

The process revealed many strengths. Foresight is highly consultative and allows us to address many difficult issues Australia faces in keeping pace with change, particularly in fast growing and dynamic sectors of the economy. It can help us identify and consider issues such as fostering attitudinal change in Australian society, and increasing industry's commitment to research and development (R&D) as part of achieving competitiveness and prosperity.

It is useful to link the relatively new process of foresight with the more familiar world of corporate strategic planning. A model of such an application is presented in Chapter 3. The comparison demonstrates for me the power of foresight as an effective aid to S&T strategic planning. It is a useful analogy, I believe, in aiding the comprehension of the outputs and the process of foresight as applied by ASTEC.

A product of the study has been a better appreciation of the interrelationships between science, technology and the economy in the Australian context. The reality is that Australia is a small player, that our contribution to pure science on a world scale is of the order of two per cent, and we need to comprehend the implications of this in optimising our S&T efforts and skills base with regard to overall national well being. There is no doubt that planning R&D is controversial; however, it is an issue that we must face.

We should not be surprised to note that the first round of this Australian foresight process reveals a different emphasis to that of many overseas studies. For example, while we stressed *Global Integration, Applying Information and Communications Technologies, Environmental Sustainability, and Advances in Biological Technologies*, which are reflected overseas, international studies also identify the critical future importance of manufacturing-related S&T. In particular, overseas studies have identified the high significance of precision and control in

management, and new materials, which did not emerge from the ASTEC foresight study. It is possible that these omissions reflect some gaps in the ASTEC consultation process, or the high importance accorded to manufacturing in many other countries.

Foresight provides the opportunity for governments to adopt a catalytic role in working with industry to develop new competitive strengths. ASTEC identified many potential export opportunities for a variety of industry sectors in Australia. Capturing these opportunities will require a proactive approach, involving industry, to further examine opportunities and constraints in detail, including those arising outside the S&T system, such as access to capital.

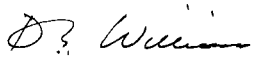
It is also probably necessary to emphasise that the outputs of ASTEC's study should not be seen as prescriptive. We have not sought to identify specific scientific or technological developments for 2010. Rather, we have sought to emphasise the value of 'foresight' as a tool in managing change, and to address broad issues of skills, culture, innovation and communications.

If I had to identify a single, critical priority to emerge from this approach, it is the need to develop Australia's technological literacy as part of the inculcation in the young of a spirit of enterprise. This must start at the primary education level and continue through all levels and forms of education and training. Initiatives in this regard should be at the top of the list for actions. ASTEC has proposed that S&T education in primary school be the subject of a flow-on study of great urgency.

In conclusion, I would like to thank all the people who have contributed so generously to this study. This includes the Reference Group, all those who provided input by way of responses to the call for submissions, the Key Issues Roundtable meeting participants and all those involved in the Partnerships. In particular, I would like to thank all my fellow Councillors who made many strong contributions. The overall responsibility of directing the study fell to Ron Johnston who, as Convenor, worked tirelessly and enthusiastically to structure and direct the study and to promote Australian participation in the foresight process, both nationally and internationally. The importance of the input of the ASTEC Secretariat, their enthusiasm, skills and effort cannot be overestimated.

This study is a first for Australia and has demonstrated the importance of foresight as a method for re-directing the mindset of this country, as it must be, and the paramount importance of S&T in securing the future well being of all Australians.

A strong science, technology and engineering system is essential to managing the uncertainties ahead. It is in this context that ASTEC considers foresight to be a useful tool for fine-tuning our S&T activities, to achieve better outcomes in the longer term.



D G WILLIAMS
Chairman of ASTEC
May 1996

Executive summary

This is a summary report of the ASTEC study *Matching Science and Technology to Future Needs: 2010*, which brings together the main outcomes of a number of mini-studies, broad ranging consultations, extensive literature reviews and analysis of overseas foresight experiences. A full version provides additional background material.

A Reference Group of more than 30 eminent Australians assisted ASTEC to develop a set of six *Key Issues for Australia to 2010*, which then became the focus of our broader consultations. Detailed Partnership studies with major Australian organisations, Roundtables which discussed certain of the Key Issues and two major consultancies led us to identify four *Key Forces for Change*.

The study is one of the most ambitious and complex ASTEC has undertaken.

What Does the Future Hold?

If we knew the future we could minimise the risks of decisions we take today. There are many ideas about what might happen and many attempts by experts to develop predictions. These, often based on trend analysis, collectively form an 'expected scenario' for 2010, which underpins much current long-term strategic planning and decision-making. The following is a summary of ASTEC's interpretation of the common elements of this expected 'global future' (see Chapter 4 for more detail).

In 2010 economies are expected to be market based. There will be a greater international focus, with stronger regional groupings and a widening gap between industrialised and developing countries. Even though there will be more global institutions, and greater agreement on many matters, there will also be an increased potential for more localised conflicts. Wealthy industrialised countries with aging conservative populations will be trying to protect their position, while poor countries with rapidly increasing numbers of young citizens try to survive. A small number of countries, particularly those in Asia, will have moved from developing to industrialised status, and their increased savings and national economic growth will make them, and the Asia-Pacific region, the main engine of growth in the global economy. International and intra-regional trade in goods and services will increase, with an emphasis on off-shore production and sophisticated high-technology. Resource distribution will be even more inequitable so that poorer countries do not have sufficient water, food or energy, and their problems are exacerbated by cycles of environmental destruction, resource depletion and increasing debt. While the environment of poorer countries is worsening, it will become a higher priority for rich countries and for the newly industrialising countries who want cleaner air and water as part of improved living standards.

The future will not unfold exactly like this. Unexpected events will emerge, changing the future in significant ways, although our values and preferences as a community will temper just how these events unfold. Plans which rely too heavily on an expected future risk failure.

To develop a more comprehensive picture of the future, built on combining perspectives of 'expected', 'preferred' and 'possible' alternative futures, we adopted the processes of 'foresight'. The objective of the approach was to enable us to manage the uncertainties ahead.

Foresight processes were used to develop alternative perspectives on Australia's longer-term requirements for science and technology (S&T), including engineering. ASTEC obtained a considered view about the direction and nature of change on the eve of the 21st Century, its implications, and how we might better position ourselves to respond to the challenges of shaping our future.

ASTEC developed a distinctive approach to foresight – a 'demand-driven' view. This contrasts with the emphasis of many international foresight exercises, which primarily identify new developments in S&T. ASTEC believes Australia needs a broader view of possible futures which, from the outset, sees S&T as a tool to achieve economic, social and environmental goals.

Four Key Forces for Change to 2010

From analysis of the outcomes of our consultations and mini-studies, we have identified four key forces which are destined to affect our futures in many ways. We must prepare ourselves to manage and shape them to meet our needs into the 21st Century. While they will impact in various ways on industrial sectors and groups within our multicultural and diverse society, we must all understand the implications of these *Key Forces for Change*:

- *Global Integration*;
- *Applying Information and Communications Technologies*;
- *Environmental Sustainability;* and
- *Advances in Biological Technologies*.

These Key Forces, singly and combined, will change our lives over many years to come. They can significantly change the way people conceptualise the world around them and the way it operates. We are already experiencing changes due to globalisation, increased environmental awareness and the rapid developments in computers and telecommunications. These are expected to accelerate over the next 15 years. However, our capacity to respond to advances in genetic and biological technologies is still in its infancy. We are only beginning to understand their potential and deal with their wider implications.

ASTEC suggests that to assist us prepare for the challenges these Key Forces will bring, areas for action are to:

- *develop a set of strategic principles to guide Australia's proactive participation in a variety of international fora, and to encourage the demonstration and promotion of sectoral benchmarking within Australian companies;*
- *ensure that information and communications technologies (I&CT)*

are integrated as a key component within all sectors and that all Australians are skilled to provide a flexible response to the challenge of these technologies;

- *establish the broad parameters for a system of resource accounting in Australia and its scientific and technological requirements, and the development of infrastructure and strategic research in this area; and*
- *develop guidelines for ethical, environmental and equity issues arising from biotechnology developments, eg genetic treatment and testing of humans; and a suitable regulatory environment across all States and Territories.*

The importance of S&T will grow over the next 15 years as the world changes. People in all walks of life will be required to make decisions about scientific knowledge and technological applications in their everyday lives. S&T experts must be prepared to answer these community needs and adapt to working in new ways – increasingly through expanding multi-disciplinary networks.

The S&T system will be required to play an increasing role if we are to meet our national goals of a creative, productive, inclusive and ecologically sustainable Australia into the 21st Century.

Managing the Impacts of the Key Forces for Change

ASTEC expects the *Key Forces for Change* will have significant impacts on industry, government and the community.

For industry, the unfolding of a particular sector's future will depend on responses to a unique set of long-term issues, drivers and constraints. A long-term perspective indicates the value of adopting a sectoral industry-driven approach to innovation policy and the development of strategic perspectives on future competitiveness. ASTEC's Partnership studies demonstrated the value of taking a targeted approach.

Global markets will bring greater competition for Australian industry – we need to focus on our strengths and to develop and maintain competitive advantage. Enhancing economic growth through an increased research and development (R&D) growth could contribute an estimated $60 billion to national income over a 10 year period.[1]

There is wide agreement that innovation will be critical to Australia's success in the 21st Century. A culture which adapts to change, uncertainty, newness, complexity and the novelty of different approaches is required for innovation to flourish. Foresight can assist the development of an innovative culture.

New opportunities for industry are emerging as a result of the Key Forces for Change. Success in such business will depend to a large extent on using these forces to advantage. This report suggests future opportunities will require a stronger knowledge base, including a skilled workforce, a good R&D infrastructure and an enhanced capacity for technology transfer. Opportunities were identified for Australian businesses in developing information-based international services, applying sophisticated technology in new ways and integrating business systems into global networks.

Over the next 15 years, Australian governments are expected to face many challenges requiring them to re-assess their roles. They will need to prioritise the acquisition and use of S&T in new policy frameworks on a regional, national and international basis for issues varying from urban water, defence, I&CT, to aging populations. While many current initiatives are targeted in the areas of the Key Forces, ASTEC questions whether we are giving them a sufficient priority.

The last decades have brought immense and often unforeseen changes in the role played by S&T in our daily lives in areas ranging from sport to security, from shopping to employment. Some groups, especially young people, Aboriginal and Torres Strait Islander communities and communities in regional Australia, questioned whether S&T really meets community priorities. They have argued that S&T needs to change significantly if their needs and priorities over the next 15 years are to be met and Australia is to realise its goal of an inclusive society.

To ensure that we are prepared as a nation to face the challenges of the future, government must help Australians to understand the Forces for Change, to shape them for our longer-term benefit and to benchmark the appropriateness of our plans for the future against them.

ASTEC identified areas for action to:

- *develop a targeted strategic approach to industry advice on innovation and, in partnership with industry, review the implications of foresight for competitiveness;*
- *collect and disseminate information on emerging characteristics of new businesses and industries, including information on the complex relationships between S&T and economic growth in specific sectors;*
- *examine the scope and adequacy of sources of information on relevant science, engineering and technology in Commonwealth Departments and Agencies, and to consider the identification or appointment of science and technology advisers; and*
- *consult with Aboriginal and Torres Strait Islander communities, particularly in isolated regions, about their capacity to access infrastructure to develop, undertake and evaluate appropriate science and technology; and to explore options for developing infrastructure programs.*

A Science and Technology System to Meet Broad Challenges Ahead

Two out of three young Australians believe S&T offers the best chance to meet the challenges ahead. The S&T system, both in industry and government, must be designed to do this effectively. Considerable change is needed and much of this must be motivated from within, as part of a re-think of the role of S&T into the 21st Century.[2]

The scale and complexity of the potential challenges ahead require a broad-based response. An essential part of the response must come from the S&T system. The requirement is a forward looking S&T system that is better integrated with socio-economic and environmental needs.

This suggests an S&T community that is more aware of, and responsive to, broad community concerns. An S&T system that meets the broader community 'half-way' is likely to foster increased understanding of, and respect for, S&T.

An important aspect is a capacity to capture opportunities and competitive advantages from future technology. As part of our study, ASTEC considered six international generic priorities or 'critical technology' areas for the 21st Century:

- environment (including energy);
- transportation;
- information and communications technology and electronics;
- genetics and biotechnology;
- manufacturing and precision and control in management; and
- new materials.

Prospective technological developments in these areas are considered internationally to be particularly important to the achievement of national goals, eg wealth creation or community well-being. They have much in common with ASTEC's four Key Forces for Change.

ASTEC has assessed Australia's performance in these critical technology areas.[3] International comparisons reveal relative Australian strength in science related to biotechnology and genetics, and environment (including energy), but some concerns were expressed about our capacity to build commercial success from this expertise. Australia has niches of strength in I&CT and transport, but a weak position in precision and control in manufacturing and new materials.[4] ASTEC suggests that Australia's relatively weak position in the latter two areas might reflect the high importance accorded to manufacturing in many other countries. Means to develop Australian capability in these areas needs to be further investigated.

Many of the new technologies to 2010 are characterised by the convergence of a number of component technologies. This creates the need for networked international and multi-disciplinary effort. Many of the policy issues they raise, such as intellectual property and commercialisation of new ideas, require the development of effective links between S&T and the finance and legal systems. Developing such links is a critical long-term issue.

The global S&T system is becoming more integrated, raising questions about how we can best benefit from the changing situation. Australia is part of a dynamic region which is rapidly expanding its S&T effort. Australia's S&T system is, in many ways complementary to this effort. In particular, our strengths in biotechnology and environment could enhance Australia's long-term future through mutually beneficial collaborations with our Asian neighbours.

Foresight can identify critical skills for the future. Four areas of 'generic' skills required to better prepare the S&T system for the challenges ahead are: management, international relations, applying I&CT, and risk management. These are particularly important for enhancing the commercialisation of Australian ideas.

ASTEC suggests that areas for action are to:

- *promote an S&T system which is integrated into its social and industrial context and, while committed to excellence, is also open and responsive to social and ethical issues;*
- *review of Australia's relative strengths and weaknesses in emerging 'hot spots' in research and technology, and commercial prospects into the 21st century, and of barriers to the development of inter- and multi-disciplinary research;*
- *review existing 'national benefit' criteria for Australia involvement in international science, engineering and technology activities, and evaluate Australia's ability to provide relevant and timely scientific and technological information to support Australia's strategic needs in international negotiations; and*
- *encourage organisations responsible for S&T (including industry, government, and relevant academies and professional organisations) to review how well they are building generic skills for managing change into the 21st Century.*

Embedding Science and Technology in Australian Culture

The field of S&T will be increasingly important to Australia's ability to meet the challenges of the 21st Century. The level of understanding of S&T across the Australian community is an important factor in determining the extent to which Australia can use this powerful tool. As individuals, and as a community, we need to incorporate socio-economic, environmental and S&T factors into all decision-making. A much better level of knowledge, understanding and skills in S&T is needed for all Australians.

For many years, literacy and numeracy have been the cornerstones of western industrialised education. Yet many people have questioned its adequacy for a more technological age that requires new skills in technology and problem solving. ASTEC proposes the framework for considering this is 'technacy'. Technacy is a way of defining the meaning of 'technological literacy' that goes beyond competency in using technology. It refers to a holistic view of technology problem solving, communication and practice that includes consideration of social, ethical, technical and environmental resources and constraints.

ASTEC suggests that the Commonwealth Government support the development of improved S&T skills by integrating 'technacy' in all primary and secondary school curricula and teaching practices.

ASTEC has demonstrated that foresight is a useful tool in assisting us to meet our goals for the future. Determining research priorities and improving the capacity for long-term planning are only two of these. Overseas experience has proven that it can also build consensus, assist communication between different groups and act as a focus in developing a longer-term commitment and vision of the future.

We have the capacity as a nation to meet the challenges ahead successfully. Australians are very interested in the future and want a national framework to build a longer-term perspective. People are encouraged by the foresight process; through it, they can develop a confidence about their ability to manage the future. If we are to harness such enthusiasm for the future we need to build an ongoing national capacity for foresight.

ASTEC suggests that the Commonwealth Government encourage government, industry, research and educational organisations, professional societies, peak bodies and community groups to undertake, or be involved in, foresight exercises.

Foresight, which develops a rich context for S&T decision-making, allows us to anticipate potential consequences of current decisions. This can help us shape the present, to better meet our future needs.

Introduction

We present here a summary report of the ASTEC study *Matching Science and Technology to Future Needs: 2010*. The full version provides considerable additional background material supporting the conclusions presented here.

A Reference Group of over 30 eminent Australians, well known in industry, government and the broader community, were our primary advisers for the study. We undertook extensive consultations, including several surveys of the community and science and technology (S&T) experts, targeted industry interviews, sector and issue-based and regional consultations. The report builds on a broad base of information and opinions – tested and retested.

Our study brought together the outcomes of thirteen separate mini-studies, a broad range of consultations, extensive literature reviews and analysis of overseas foresight experience. Based on an initial 'Overview', we established a set of six Key Issues for Australia to 2010, which then became the focus of our investigations. We initiated detailed studies in five Partnerships involving more than 20 major Australian organisations; developed Roundtables to discuss certain of the Key Issues; and established two major consultancies on the contribution of S&T to economic growth and Australia's position in internationally identified critical technologies. The study is one of the most ambitious and complex ASTEC has undertaken.

Australians are increasingly aware that we can no longer rely on natural resources for wealth and long-term prosperity. Nor can prosperity any longer be guaranteed. We live in a complex world where technologies that did not exist a few decades ago are playing key roles in our social and economic life. We now understand that the development, acquisition and application of knowledge through science, technology and innovation can create new sources of wealth and improve the quality of our lives. Knowledge and skills have become key factors in developing and sustaining international competitiveness.

New technical possibilities from scientific and technological innovations present opportunities for industry to develop and grow. New demands and needs are emerging that S&T, including engineering, can help to satisfy. By looking forward to possible future developments and their implications for research, the economy and society, we can obtain a valuable alternative perspective on our present activities.

Mechanisms have been developed for systematically looking ahead. 'Technology foresight' or 'foresight' processes are well established overseas, notably in Japan, and are under development in Europe and the United States of America. Foresight is being used to contribute to policy development and investment decisions in both the public and private sectors. Companies such as

Shell, Philips and Hitachi focus on the long-term to achieve competitive advantage.

Many Australian institutions are casting their horizons further ahead. ASTEC decided it was important for Australia to investigate how we can benefit from the application of foresight methods to S&T and as a result the use of foresight has been the focus of this study.

chapter 2

What is 'foresight'?

The Macquarie Dictionary defines 'foresight' as: 1. care or provision for the future; 2. the act or power of foreseeing; 3. perception gained by or as by looking forward.

In this report, 'foresight' has a special meaning, referring in addition to the growing field of 'science and technology (S&T) foresight'. This field seeks to use various types of information about prospective scientific, technological and other developments as inputs to decisions on priorities and research directions.

Foresight attempts to capture the dynamics of change by placing today's decisions into a context that includes the possible developments of tomorrow. It is not intended to replace more traditional methods of analysis, nor to define policy. It seeks to add a new dimension to our thinking.

The process has a number of important characteristics. In particular, it is:

- a way of thinking about the longer-term future and how it could differ from the present;
- a means for testing our current views and policy settings; and
- one way of overcoming the difficulties of a static or backward looking analysis.

Foresight acknowledges a range of possible futures. It provides a valuable opportunity to think seriously about significant technical trends and their relationship to socio-economic needs. Unlike 'forecasting', it does not attempt to estimate or predict what the future *will* be. Foresight implies an active approach to the future and reflects the belief that the future can be influenced through actions we choose to take today. Many decisions involving investment in S&T have long lead times, which makes it important to have an informed view about the future.

To develop its perspectives on the future, ASTEC combined information and opinion from across the study to build perspectives on expected futures, possible futures and preferred futures:

- *expected futures* are the analyses of experts based on current trends and extrapolations;
- *preferred futures* are those we as a community want to achieve – individual values, strategies of corporations and community organisations, and government policies; and
- *possible futures* provide a range of options for a world which might change significantly over time – critical uncertainties and trend breakers.

The exercise built pictures of 2010 in a broad context for identifying our future needs. It is only when we have built complex pictures of alternative futures that we will be able to assess how well our

current S&T system is positioning itself to meet our future needs.

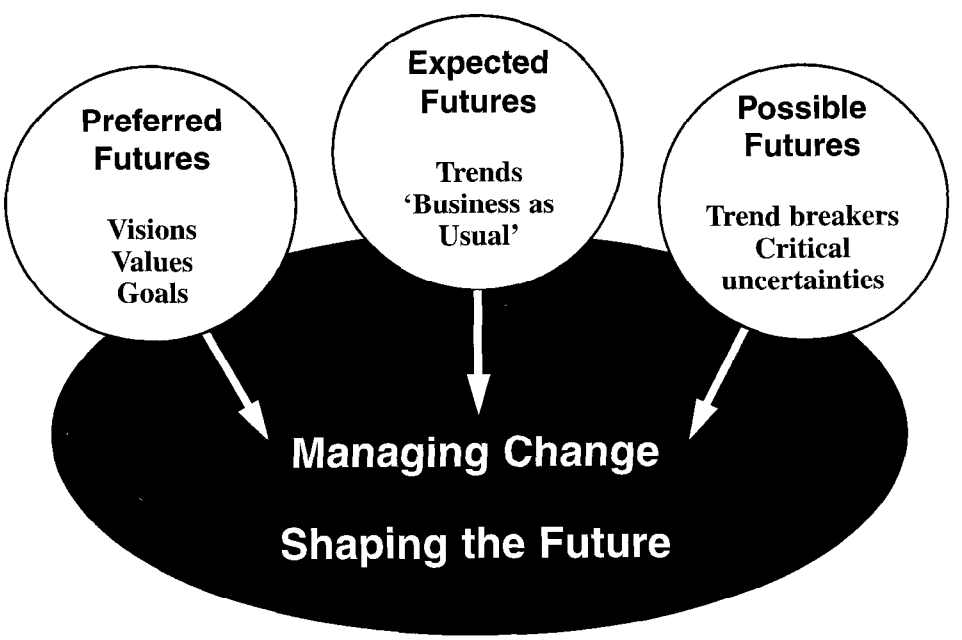
The assumptions which underpin foresight methodology are different from those of forecasting techniques, and indeed of modern science. While foresight uses some of the same techniques, eg trend analysis, it provides a different context for understanding the findings. Rather than a primary emphasis on prediction, foresight acknowledges that addressing the future necessitates the management of uncertainty. Foresight involves a process by which a richer and well-informed context for current decisions is developed through a dialogue among relevant stakeholders; it is both active and responsive: an extension of human abilities of forethought, creativity, analysis and judgement, leading to action.

It is now well accepted that the process of foresight requires consultation and interaction between scientific experts, research users, policy-makers and the wider community. In this way, a broad range of perspectives can be explored – the wider the involvement, the more broadly the benefits will be felt.

It is also clear from overseas experience that foresight processes must be transparent. They must allow the underlying assumptions, analytical framework and data inputs to be subject to external scrutiny. Such openness also allows non-conformist views to be given equal weighting with conventional ones and allows the possibility of identifying emerging paradigms.

In conducting foresight it is necessary to maintain a balanced perspective between

Box 1. 'Foresight' – an approach to managing change



the supply and demand factors that influence future developments. In particular:

- supply factors include the creation of new technological or commercial opportunities by scientific research, and Australia's strength and resources to exploit them, eg our world class agricultural research; and
- developments in technology and production can create a use for existing and novel science through the mechanism of demand-pull – demand factors include the priorities and needs of the broader community eg, the need to alleviate soil degradation.

It is through the interaction of these main elements that successful innovation occurs and the adoption and use of imported technology is mediated.

The ASTEC approach

This complex study aimed to provide an information base to assist government and industry to make better informed longer-term decisions on the development and application of science and technology (S&T). It examined possible national and global changes to 2010 and Australia's key future needs and opportunities that rely on, or could be significantly affected by, scientific developments and the application of technology.

The study involved many thousands of people, a series of separate consultancies and drew on international foresight studies, eg, from the UK, US and Japan. It was based on an iterative process of identifying, testing and retesting ideas through extensive consultations with experts in S&T and other areas, often in partnership with other organisations. A feature of our study is its very broad base of information and opinions, including inputs from S&T users, providers and policy advisers in both the private and public sectors.

Special features of the ASTEC approach, developed to fit the Australian context, were:

- a catalytic role by ASTEC with emphasis on process, consultation and involvement;
- a multi-stream mosaic of selective studies and a wide overview with the use of multiple methodologies;
- a demand rather than supply-driven approach, with emphasis on needs for S&T in achieving preferred futures; and
- a significant use of overseas studies to establish the general supply conditions for S&T.

Important elements of the study, which are frequently referred to in this report are shown in Box 2. These are:

Reference Group – ASTEC established a Reference Group as the primary advisory body for this study and to ensure that the views of key groups were considered. The members are listed in Appendix A. ASTEC also worked with the Prime Minister's Science and Engineering Council, and with the Coordination Committee on Science and Technology, to ensure that its work was widely known and understood within the Commonwealth science, engineering and technology advisory system.

Partnerships – in-depth, specific sector foresighting studies jointly conducted with other organisations. Separate reports are available for each Partnership. These used individually designed foresighting processes to identify S&T opportunities and requirements over the next 15 years and demonstrated that foresighting is useful to a wide range of groups in their long-term planning. They investigated how specific S&T capabilities will impact on the realisation of preferred futures and found that broad participation in foresighting

results in cohesive sector strategic planning; forcsight methodologies could be tailored to individual sector/area needs. Partnerships were in the areas of:

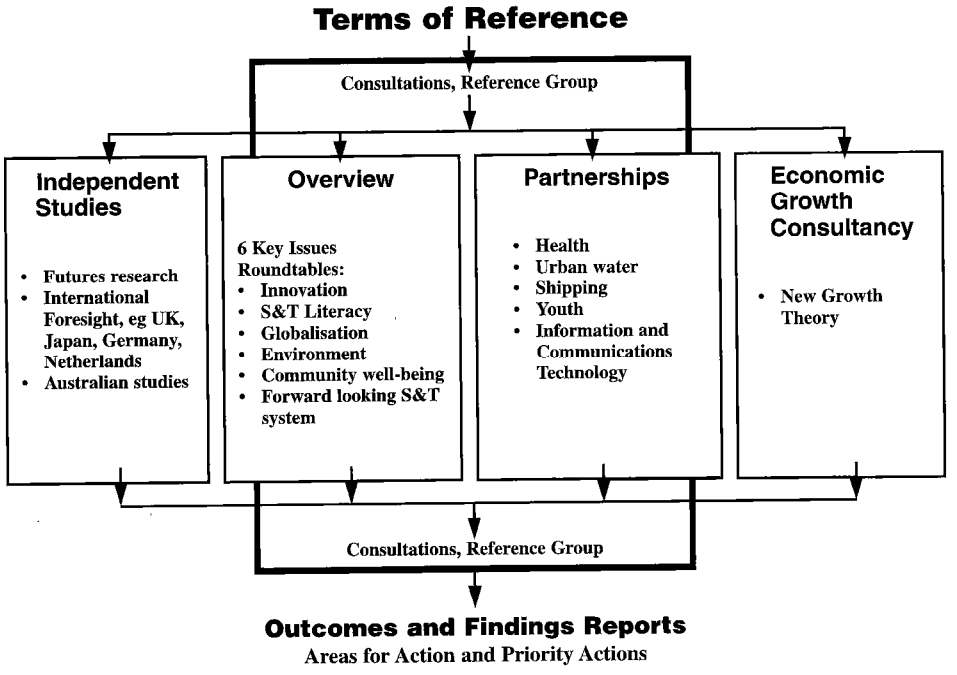
- urban water life cycles;
- information and communications technology;
- health, neuro-degenerative diseases in older people;
- youth; and
- shipping.

Overview – This aspect took a broad approach to both supply and demand issues to 2010 and sought inputs from S&T users, providers and policy advisers in the private and public sectors. It was focused through the identification of key issues for Australia. Roundtables involving groups of up to 50 different experts discussed the following Key Issues for Australia to 2010:

- *the need for innovation and entrepreneurship*;
- *the need for a technologically literate society*;
- *the need to capture opportunities from globalisation*;
- *the need to sustain our natural environment*;
- *the need for continuous improvements in community well-being; and*
- *the need to build a forward-looking science and technology system.*

Economic Growth Study – a major consultancy on the role of S&T in wealth creation and whether economic growth limits might be lifted through additional

Box 2. Elements of the Study



investment in research and development (R&D).

Independent Studies – ensured that the knowledge of other groups conducting their own future-oriented analysis will be taken into account. As part of this approach, ASTEC obtained information about the experience of other countries in technology foresight, particularly Japan, the United Kingdom, the United States, Germany and the Netherlands. ASTEC also provided support, through materials, advice and workshops, to organisations seeking assistance on foresight activities. In addition, ASTEC commissioned a review of international foresight and its implications for Australia.

Key Forces for Change – are used as the organising device for gathering together the vast number of elements of probable, possible and preferred futures, in order to examine their implications, challenges and opportunities for Australia in general and our S&T system in particular.

Areas for Action – these are not traditional recommendations. They have been designed to highlight areas of action where governments and others can develop potentially powerful levers for responding to the issues identified. The design of specific actions and programs should rest with the relevant stakeholders. In a few selected cases where potential actions were clear, ASTEC has made recommendations for specific Commonwealth Government actions.

ASTEC believes that the application of foresight can be a practical and useful exercise for many organisations. In particular, foresight is readily adaptable to industry and can be used as part of corporate strategic planning processes. To illustrate this potential, Box 3 provides a comparison between the elements of a corporate strategic model and the process and the outputs of the ASTEC study. This reveals a strong correlation. Linkages between the elements of the model are illustrated in Box 4.

Box 3. ASTEC's foresight study viewed from a corporate strategic perspective

S&T foresight is often proposed only as an aid to strategic planning and in this role it is a powerful and practical tool. Managers need to be able to look ahead with confidence to make strategic choices and investments today, in anticipation of uncertain future returns. Foresight allows managers to consider strengths, weaknesses, opportunities and threats in a dynamic context provided by long-term perspectives. It brings together the consideration of many factors crucial to competitiveness and innovation, such as helping identify commercially valuable research areas and indicating emerging market needs.

Yet the processes of foresight can be viewed as linking even more closely with the techno-industrial planning model. The following diagram compares the process and the outputs of the ASTEC study with the elements of a more traditional corporate strategic model. The model is largely self explanatory; however a few words of explanation and a few caveats are appropriate.

The *Vision* and *Objectives* statements show both the ASTEC Vision and Objectives, as set out in the ASTEC Act, and the Vision and Objectives as set out in the Terms of Reference for this Study. The correlation between the two reinforces the basis and scope of the study. The *Mission* Statement makes the point that ASTEC's basic role is to furnish advice to government. While a very important output of this study is the impact of the foresight process on the S&T culture of Australia, the specific output, the *Tactics*, are advice to government.

A suggested set of Goals is shown in the model, but without quantification, which remains a task for the future. The goals deserve urgent evaluation as part of a framework for accelerating economic growth in Australia and the rate at which we become a more technologically literate society.

The strengths, weaknesses, opportunities and threats (SWOT) analysis lists the various parts of the foresight process employed by ASTEC. The Overview captured the general views of a broad cross section of the Australian community, the Partnerships were foresight exercises on some specific areas of S&T activity or community interest, the Independent Studies constituted a review of national and international foresight and foresight type studies, and the Economic Growth Consultancy was a first cut at applying new growth economic theory to evaluate the contribution of S&T to overall economic growth in Australia.

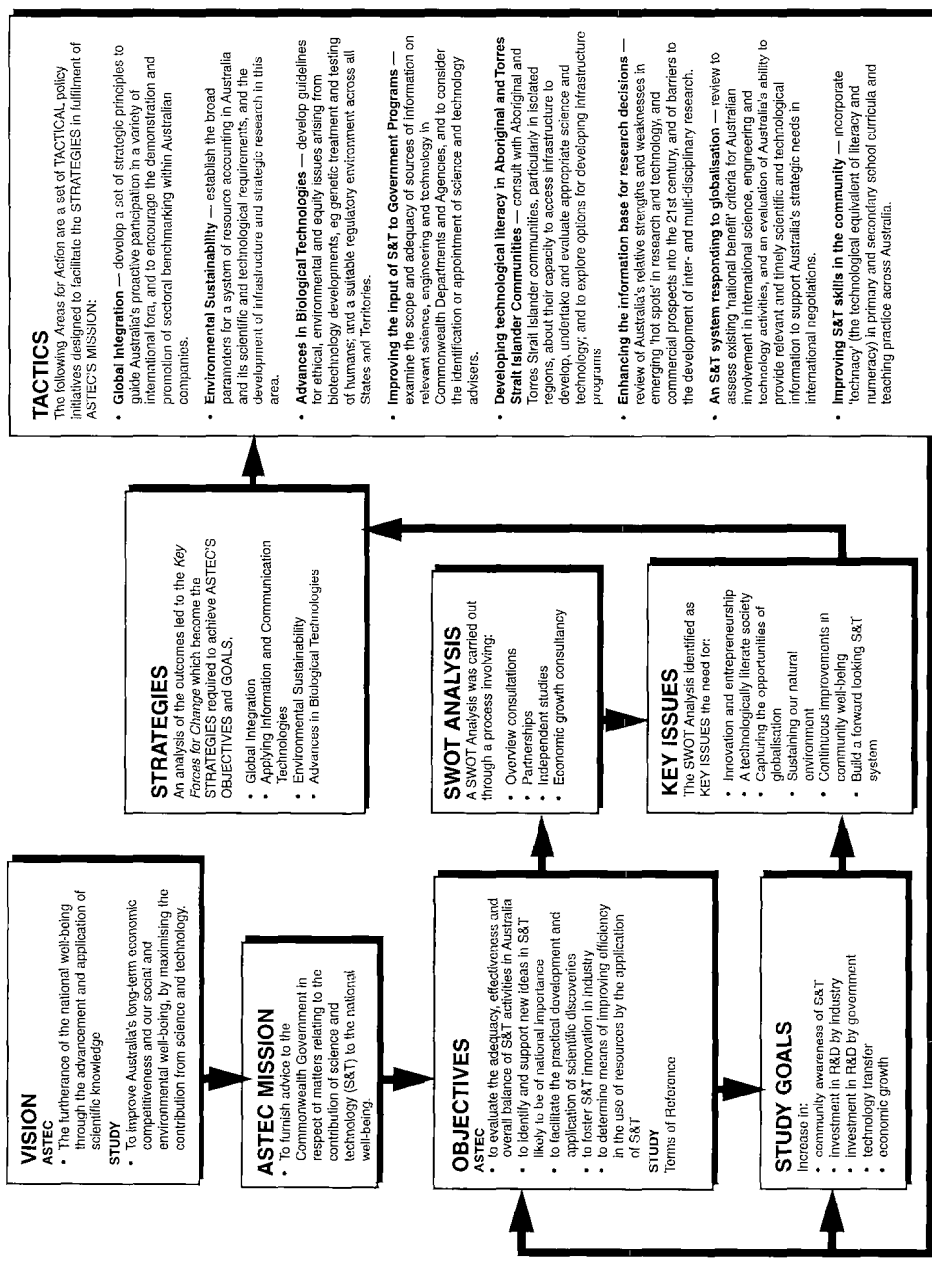
The first major output of the study was the set of *Key Issues* shown in the model. These emerged from the extensive consultation process of the Overview and were reinforced to varying degrees in the Partnerships and other consultations. ASTEC's consultations and the analysis of its inputs also identified a list of important export opportunities for Australia and provided the perspectives which were a major determinant of the strategic priorities.

The next two steps in the process distinguish this study. Analysis of the Key Issues and all the other vision and advice collected in the consultations led clearly to four Key Forces for Change. These in effect are the Strategies which will link the Objectives and Goals with the Key Issues. ASTEC acknowledges that second and later foresight iterations will lead to modifications to the list as the national and international priorities change.

As with the Key Issues the Key Forces for Change are not entirely novel, nor should they be expected to be. The difference is that they have emerged from a process of consultation and analysis and hence there is a basis, a logic in their prioritisation, to form the primary set of future drivers for Australia, as perceived by Australians in 1995.

The Study produced a database of ideas ranging from Key Issues through Key Forces for Change or Strategies, to more detailed tactical suggestions relating to how the particular concern might be addressed and the specific objective or goal achieved. These are captured under the heading of *Tactics* in the model. While these are primarily for government, which is the Mission of ASTEC, many of them have application more broadly, in industry, in the education arena and for the community at large.

Box 4. Diagrammatic representation of foresight related to a corporate strategic planning model



Perspectives on 2010

ASTEC combined information and opinion gathered from across the study to build perspectives on 'expected', 'preferred' and 'possible' futures to 2010. This provides a broad context for identifying our future needs and enabling us to assess how well our current science, engineering and technology system is positioning itself to meet these needs.

When it comes to the future, most of us carry only one picture around in our heads; a personal view of what tomorrow will be like. This view is generally only poorly defined and based on a continuation of the present – a 'business as usual' approach.

Many experts have made predictions, based on analyses of current trends and extrapolations, which collectively form an 'expected scenario' for 2010. These analyses are very useful on issues such as demographics and trends in resource use; however, they tend to take little account of unforeseen circumstances. ASTEC's interpretation of a common view that underpins much current 'futures' thinking and strategic planning and decision-making is given in Box 5.

Box 5. ASTEC's interpretation of an 'expected' view of the world to 2010

In 2010 there is expected to be an even greater emphasis on market forces, a stronger international focus, a revival of nationalism and a wider gap between industrialised and developing countries. New global institutions and increased international agreement on many matters will not discourage an increase in localised conflicts. Three regional groupings of Europe, the Americas and the Asia-Pacific region will be increasingly important – with large amounts of intra-regional trade and increasing national powers being given to regional bodies.

Wealthy industrialised countries with declining populations of aging and conservative citizens will be trying to protect their position against developing countries experiencing rapid increases in their more youthful populations. A small number of countries, particularly from Asia, will have moved from developing to industrialised. Their increased savings and rapid economic growth will make the Asia-Pacific region the growth area of the global economy.

Trade growth will be concentrated particularly in the areas of high technology goods and services and with an emphasis on off-shore production. Global companies based in many countries will escape control by individual nations and the global financial markets will become more powerful, increasing their influence on the policies of national governments.

While theoretically the levels of global resources are sufficient for the increased population of 2010, inequalities in their distribution will mean that poorer countries will not have sufficient water, food or energy – problems exacerbated by cycles of environmental degradation, resource depletion and increasing debt. Declining living standards in heavily indebted countries may increase political violence and force concessions on debt payments. Conserving the environment will become an even higher priority for industrialised countries and the emerging middle classes of the newly industrialised countries will demand cleaner air, land, water, etc. Set against this will be tensions arising from energy use and an enhanced greenhouse effect.

The values and aspirations of Australians will influence the realisation of prospective futures. People will attempt to shape the future in ways consistent with their values and aspirations – to realise a 'preferred' future and to overcome concerns. ASTEC obtained views on these from many sources.

Responses from the community to ASTEC's call for submissions highlighted three broad areas of concern, each expressed in the context of the need for a strong economy.

The environment was nominated by over fifty per cent of people from both urban and rural areas, unions, community groups, academics, business people and government officials. Environmental issues identified included the Greenhouse effect, marine and air pollution, land degradation, conservation of the natural environment, retention of biodiversity, protection of forests, population, water quality and energy options. We need to consider how best science and technology (S&T) might be used to manage such issues. Substantial opportunities for Australian S&T were anticipated to flow from new environmentally friendly technologies, eg waste munchers, water purifiers and solar power.

A second theme was a growing concern about *Australia's place in a changing world*. Australians no longer see themselves as separate and geographically isolated from the rest of the world. We have come to realise that we must find a place in a global community, with Asia on our doorstep.

The third theme related more specifically to *S&T issues*. Concerns emerged about the need for developing a more technologically literate society, valuing our scientists, technological innovation and sovereignty, the need to be a clever country, the commercialisation of new technology and the role of S&T in small and medium-sized enterprises.

ASTEC's prime advisers in this project – the Reference Group – endorsed the community's emphasis on ecologically sustainable development, Australia's role in a borderless world and the potentially critical role of S&T. They added concerns about the changing role of work, an aging society and health care, and the importance of the information society and the over-riding need for sustained economic growth.

Overall, a fascinating picture emerged of:

- an Australia with no effective borders, as new global information and communications technologies combine with the abolition of passports;
- significant changes to the way we view work as the number of jobs is reduced, Australians move towards self employment, the link between income and work is further weakened and the gap widens between haves and have nots;
- Australia's place as the only European nation of Asia and our ability to become a dynamic 'node' in the global economy; and
- an aging society, facing increasing disabilities as we live longer, where individuals are faced with addressing problems in their genetic make-up, and the cost of health care limits access to an affluent minority.

Other indications of preferred futures is provided by exercises leading to strategy documents, eg by groups such as the Business Council of Australia and others.[5]

In this study, the basic vision that emerged for the 'preferred future' of Australia was of a country that is creative, productive, inclusive, as well as being ecologically sustainable.

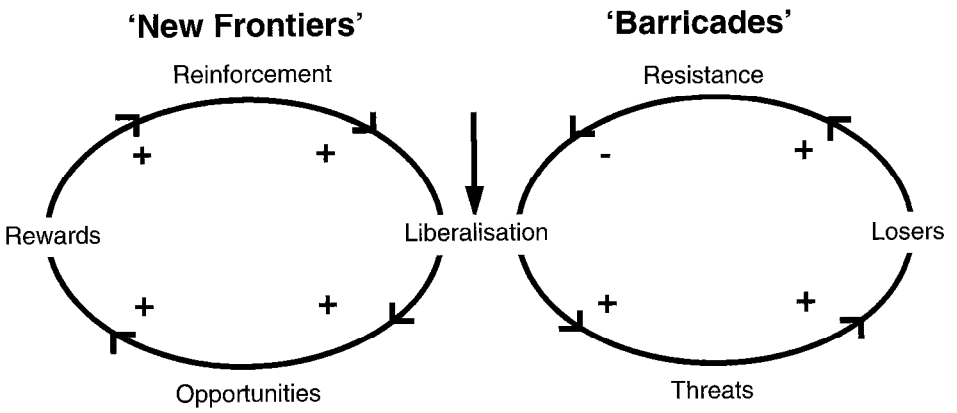
While these views can provide a useful starting point, they are not adequate if we hope to cope effectively in a rapidly changing world. We need a more flexible picture that allows us to assess alternative 'possible futures' and take account of unlikely but important events. Developing such alternatives can be achieved through 'scenario' planning approaches.[6]

Scenarios are coherent, alternative pictures of the future that combine two dimensions of risk – probability and importance. The process of developing an 'expected future' gives greater emphasis to the consideration of *probability*, whereas 'possible future' scenarios weigh *importance* more highly. One of the most important steps in imagining a range of possible futures is that there is no limit to the changes which can be considered, although many of these may later be rejected.

People undertaking foresight studies need to establish a focus to ensure that their work is useful for decision-making and establishing priorities, and maintains sufficient reality to make management sense.

One set of scenarios ASTEC found useful was that developed by Royal Dutch/Shell (Box 6). Shell has put considerable effort into the development of global scenarios over the last 15 years. The two scenarios illustrate the potential divergent responses to the driving force of global trade and economic liberalisation, and the very different implications. Together they span the breadth of possible scenarios and, from them, Shell developed robust strategies which aim to enable it to succeed regardless of what might happen, in the knowledge that reality is likely to be somewhere between the two. An important purpose of such methods is to sensitise the organisation to recognise signals of possible changes in the world and to enable quick and appropriate responses.

Box 6. Shell Global Scenarios 1992–2020



Key Issues and Key Forces for Change

Through its comprehensive consultation process, ASTEC identified the following set of six broad issues of national importance to Australia over the next 15 years:

- *The need for innovation and entrepreneurship*. A key challenge will be to manage the increasingly rapid pace of change. Innovation and entrepreneurship will help us to respond to new needs and opportunities as they arise.
- *The need for a technologically literate society*. There will be an increase in the pace with which we introduce technology into our society. The appropriate response to more technology is not to ignore it, but to accommodate it, respond to it and shape it. We need a society that can make informed choices.
- *The need to capture opportunities from globalisation*. As we move toward a global economy, countries are becoming more interdependent. Global processes are creating a new distribution of wealth, skills, technology and production. Australia must identify and capture the opportunities in this evolving world.
- *The need to sustain our natural environment*. Our physical and biological environments are our greatest natural assets and a major inheritance for our children. Increasing development and population growth in the 21st Century must be managed in the context of a sound scientific understanding of the value of our natural environment.
- *The need for continuous improvements in community well-being*. To realise a more inclusive, cohesive, confident and productive society in the 21st Century, Australians will need to face many new challenges. Science and technology (S&T) can help solve current problems, deliver continuous improvements and meet new challenges such as aging.
- *The need to build a forward-looking science and technology system*. The strategic direction, skills and knowledge generated by S&T will impact on our ability to meet our future needs. Our S&T system must look ahead to the 21st Century and be open and responsive to early, and possibly weak, signals of change.

Each of these issues was explored through a Roundtable discussion, generally of about 50 experts from a range of areas, and involving scenarios and/or trend analysis.

A valuable approach to foresight analysis is to identify major trends or drivers for change as a framework for considering the future. To this end, ASTEC reviewed outcomes from the Roundtables and other elements of the study, eg Partnerships, and identified four long-term forces of particular relevance to the study.

These forces are considered to have pervasive impacts on our economy and society to 2010 and beyond. S&T developments underpin the rate of change in these areas and the challenges they present will require S&T as part of the response. They have the common features of being broader than a single technology or sector, being capable of profoundly changing the way we do things, and for each the next 15 years was considered to be critical to their development. These are termed the *Key Forces for Change*.[7]

Three of the Key Forces for Change emerged as particularly significant because of the widespread changes they will bring to all areas of Australia over many years. They are:

- *Global integration*: Australia's changing place in the world, the importance of our developing relationship with the Asia-Pacific region, links with other regions, concerns about national sovereignty and foreign ownership, and global institutions, free trade and tariff barriers;
- *Applying information and communications technologies* (I&CT): the potential of interactive broadband services, mobile digital communications, security and privacy, global electronic financial transactions and information access; and
- *Environmental sustainability*: the impact of a growing population on world resources, Australia's historic role as a resource-based economy, our potential as the 'food bowl' of Asia, diminishing biodiversity and the impacts of global change, opportunities in environmental management.

The fourth Key Force for Change – *Advances in Biological Technologies*, arising from developments in biological and genetic technologies, and the many opportunities and challenges they will present in areas such as health care, ethics, food design and safety, emerged as significant in the latter half of the 15 year period under examination. Some aspects of this Key Force will impact on that of Environmental Sustainability.

5.1. Global Integration

Global integration has brought profound shifts in the paradigm governing national sovereignty and international competitiveness. The blurring of national boundaries places greater emphasis on regional and local sources of competitive advantage and on skills, innovation and S&T. Paradoxically, this view of global change places more emphasis on the importance of regions, networks, clusters of businesses and an individual's creativity, than does the presently dominant 'national' perspective. Trends predicted to escalate over the next 15 years include increases in:

- export orientation;
- global networks of production and the end of mass production;
- numbers of global companies;
- levels of off-shore production;
- internationalisation of services industries;
- integration of services and manufacturing;

- localisation and regionalisation as a focus;
- globalisation of finance and savings; and
- global employment.

There is a need to understand and to respond effectively to the opportunities and the threats of global integration. Important parts of national debate about Australia in the 21st Century, are expected to be issues such as national sovereignty, foreign debt and foreign ownership in a global world and what it will mean to be an Australian.

While it is important to identify and protect Australia's short-term position, this needs to be in the context of long-term opportunities. It is therefore critical to improve the capacity of government, industry and the broader community to anticipate structural shifts in economic and political alignments and to ensure Australian industry and other organisations pursue international best practice.

At present, the significant contribution of S&T across the broad range of Australia's international activities is not widely recognised. It plays an integral, if unrecognised, role in many aspects of Australia's international activities, eg aid, shipping, housing, environment, trade, industrial relations. S&T will have an increasing impact in such areas in the future and we need to ensure that we are maximising the benefits to us. It will be central to ensuring that international standards provide a fair and level playing field. Effective Australian participation in work on standards in the Asia-Pacific Economic Cooperation forum (APEC), the Organisation for Economic Cooperation and Development (OECD), a range of United Nations fora and the World Trade Organisation, require that government agencies have an identified long-term perspective on S&T developments and seek to ensure that decisions do not harm Australian interests.

In our relations with Pacific countries, S&T can play a large role in discussions about aid and resource management issues. With newly industrialised nations, such as Indonesia, the S&T component of infrastructure and services projects, such as public telephone systems, will be important. With industrialised nations, such as those in the OECD, S&T is central to discussions on issues of standards, trade and investment.

Given our limited experience, it appears important to establish a process to monitor progress in Australia's participation in globalisation and to assess how effectively we are using S&T. The process should interpret trends and evaluate emerging responses and ensure that this information is readily available to government and industry.

Area for Action: Global Integration

ASTEC considers it necessary to develop a response to globalisation that makes the most effective use of Australian S&T. This can be achieved by actions, among others, to develop targets and benchmarks in industry and research; programs which promote Australia as a technologically advanced nation; and encourage business to become aware of, and rapidly adopt, internationally competitive business approaches.

S&T can also play a strong role in developing Australia's international relations. We need to ensure that there is a clear strategy for integrating S&T in Australia's negotiations on international trade agreements and that our S&T system can contribute effectively to the work of international bodies setting rules for business on a regional and global basis, eg for standards and intellectual property.

Priority Action for the Commonwealth Government 1

ASTEC recommends that as a priority the Minister for Science and Technology consult with the Minister for Trade to:

- establish, in consultation with relevant industry, research and statutory bodies, a set of strategic principles to guide Australia's proactive participation in a variety of international fora (eg for setting rules for global businesses in areas such as standards and intellectual property) and, in particular, to identify the needs for, and contribution of, S&T; and
- encourage the demonstration and promotion of sectoral benchmarking within Australian companies and publicise the outcomes of examples of international best practice in leading edge activities particularly in manufacturing, eg in advanced and 'intelligent' manufacturing engineering and systems and the integration of services with manufacturing exports.

5.2. Applying Information and Communication Technologies

An ability to harness, access and use information – and the sciences and technologies underlying it – will be critical to Australia's economic success, community well-being and the management of our environment in the next century. The revolution in I&CT is changing the nature of economies and societies around the world. Many consider it to underlie a new 'techno-economic paradigm', with many changes in organisational and work structures and culture.[8] I&CT has contributed to a fundamental reshaping of manufacturing and is accelerating the globalisation of service industries.

Australia is in the midst of a far-reaching transformation of its communications and information systems, prompted by the technological convergence of telecommunications, computing and broadcasting. Information infrastructures are expected to stimulate economic growth, increase productivity, create jobs, increase the quality of services and improve the quality of life. While some foresee potential problems from new I&CT, eg increased social fragmentation through the formation of new sub-cultures, there are many potential benefits. For example, I&CT can reduce disadvantages of regional isolation and facilitate direct interactions between regional centres and the rest of the world. It has the potential to revitalise rural and remote communities across Australia. The opportunities arising from the new technologies provide governments with additional means to address economic, social and environmental challenges. An important issue emerging in ASTEC's study was the need to consider access and equity in achieving benefits from applying I&CT.

I&CT is expected to provide a more 'intelligent' technological regime; one where our technology and artefacts will be more interactive, communicative and responsive. A pervasive embedding of such systems into all aspects of work and everyday life presents a challenging picture of the future: global information services, 'smart' buildings and appliances, new services and leisure products, electronic cash, sophisticated farm management systems, advanced manufacturing products and processing and transport equipment.

Australia is a relatively large user of information and communications equipment and services, accounting for around 2 per cent of total world consumption. Yet, Australia's own I&CT product manufacturing industry is relatively small and immature. A major challenge for Australian business will be the acquisition and transfer of research and development (R&D) capabilities. Access to venture capital, in particular, is seen as an obstacle to the growth and development of small and medium-sized businesses.[9]

Given the rapidly changing I&CT markets and products, the challenge for government is to build the most flexible and appropriate strategy to take advantage of opportunities as they arise. The strategy cannot be built entirely on hardware and infrastructure. Instead it must be built on skills. As a nation, we need a skilled labour force, able to interpret and respond to changes. We must possess the abilities to develop new technologies and software and have the knowledge to be demanding consumers and reliable suppliers, contributing to the development of innovative solutions.

We need to ensure that the skills and capabilities are in place to use international best practice and maintain state-of-the-art knowledge in components and systems; this requires a high quality engineering base and support for longer-term research and applications.

Area for Action: Applying Information and Communications Technologies

ASTEC considers it necessary to effectively apply I&CT to develop Australia as a knowledge-based society in 2010. This will require actions to ensure that I&CT technologies are integrated as key components within all industry sectors, that Australia's I&CT infrastructure is internationally competitive and that all Australians are skilled to provide a flexible response to the challenge of these technologies.

To maximise long-term competitive and community benefits from I&CT, information services policy must contribute to enhancing awareness of the transformative impacts of I&CT on all aspects of economic and social activity – including health care delivery, training and employment, financial services, innovation and advanced manufacturing.

Actions that might be considered include work in conjunction with State governments to develop guidelines for education services at all levels, to promote high quality exposure to I&CT services and digital electronics in primary and secondary education, and to encourage life-long education for competency in I&CT. It is also necessary to ensure that the strategies to meet the information skills and infrastructure requirements of Australia industry are put in place.

5.3. Environmental Sustainability

Over the next 15 years, it is predicted that industrialised countries will apply increasing resources to achieve higher environmental standards. Emerging middle-classes in the newly industrialised countries are also expected to demand much higher standards in air and water quality and waste disposal. In these countries, rapid environmental improvements may be possible through the use of new technologies under tough environmental controls. Other countries (or regions) at the earliest stages of industrialisation will be struggling with even more serious problems. Environmental degradation will escalate cycles of poverty and increase the need for high levels of on-going international aid.

Global warming, due to an enhanced greenhouse effect, is a more uncertain threat. It is predicted to affect agricultural production, particularly coastal croplands in countries vulnerable to storm surges such as Bangladesh, Egypt and China. It could also change rainfall patterns and soil moisture, benefiting some agricultural regions at the expense of others.

The Australian environment is perceived by many people, at home and abroad, as relatively pristine and unspoiled, yet it has been severely degraded by the impact of human settlement. Soil erosion over much of the continent has risen to 10 times the natural geological rate. Nearly two-thirds of

the continent requires treatment for land degradation. Forest cover, 10 per cent of Australian land mass when European settlement began, has been halved. More than 41 million hectares of forest have been destroyed, including 75 per cent of the nation's rainforests.

Environmental management, predicted to be a huge industry world wide by 2010, presents significant opportunities for Australia. If Australia captured only two per cent of the world pollution market by the turn of the century it would generate 150,000 jobs and $8 billion in business.[10] Proper incorporation of environmental concerns into our country's economic planning frameworks will require a range of new scientific information, as well as novel methods of establishing and incorporating environmental values. Some current technologies may prove too expensive, once they have to bear their environmental costs; the economic viability of other new or emerging technologies may improve.

Do we have the scientific knowledge on which to make informed decisions on environmental issues? Can we develop new 'environmentally friendly' technologies that reflect environmental values? What are the best structures for integrating competing environmental and economic objectives?

Australia needs to be prepared for a world that could quickly move to a higher valuation of the environment. There is an advantage for Australia in implementing actions to promote realisation of a scenario that gives a higher priority to the environment. Revaluing many of our current activities, and changing priorities, will lead to more efficient use and allocation of resources and improved long-term competitiveness.

Developing S&T capabilities to support resource accounting, valuation systems, decision-making and assessment processes, cost sharing principles, the use of economic instruments and further understanding the relationship between macro-economic management and environmental conservation are critical to this new framework, to integrate the environment into decision-making.

Area for Action: Environmental Sustainability

ASTEC considers it necessary to implement actions that promote ecologically sustainable development, as a means to underpin progress towards more sustainable outcomes in government, industry and the community. The integration of the environment into economic frameworks will be an fundamental shift in developing a sustainable future. This integration will ensure that long-term costs and benefits of economic activity are considered in a broad context and will enhance not only the bases for long-term economic growth and competitiveness, but also community well-being and the preservation of diverse ecosystems.

An immediate area of action is to develop a strong national capacity in environmental economics, based on sound scientific knowledge (including resource accounting

and analysis of long-term social benefits and costs). This will require an improvement in Australia's S&T capacity to monitor and analyse changes in the environment and their impacts and values and effective mechanisms to contribute such information to decision-makers.

Priority Action for the Commonwealth Government 2

ASTEC recommends that as a priority the Minister for Environment, in conjunction with the Minister for Science and Technology, take action to:

- establish a Task Group, involving economic and scientific experts and in consultation with stakeholders, to establish the broad parameters for a system of resource accounting and its scientific and technological requirements, and develop an agreed strategy for developing our national capacity in this area;
- accelerate work on resource accounting currently underway in Commonwealth departments and agencies, and put in place the means to carry forward the strategies developed by the Task Group;
- ensure the development and maintenance of adequate infrastructure for scientific and technological efforts contributing to effective resource accounting systems; and
- encourage Commonwealth S&T funding agencies to give priority to strategic research in this area.

5.4. Advances in Biological Technologies

The 'new' biology is based on two key technologies: first, cells of living organisms can be grown as tissue cultures; and, second, the genetic material that defines the nature of these cells can be isolated and genes can be transferred from one cell to another. These technologies are revolutionising biology and all its applications.

While the main impact so far is in agriculture and medicine, applications in fields such as forensic science, security, environmental control and mining are rapidly emerging. The potential for the interface of these technologies with I&CT is just starting to be realised.

Particular applications of interest to industry include genetic modification of crops – some 50 species can be modified today. Genes can be transferred between species by a number of methods. The transfer can alter the properties of a plant, such as resistance to disease and pests, or the physical characteristics of fruits and seeds, such as shelf-life. Plants can be used as 'bio-reactors' to manufacture proteins, materials for use as drugs or in industrial processes. The Human Genome Project, a major project to map and sequence the human genome, is showing rapid progress.

Such developments may allow gene therapy, whereby malfunctioning genes are replaced by normal ones.

What is Australia's position in this global revolution in S&T related to biology? In fact, our biological science base is remarkably strong. Our standing in the scientific world is twice as strong as our national average, though we still produce only four per cent of the world's scientific publications in these fields. Unfortunately, our industrial strength in this new industry is barely recorded on the international scale. Still, we have the scientific capability within the CSIRO, higher education institutions and some emerging companies to be among the world leaders in a few targeted areas. Clearly, it is important that Australia realises opportunities provided through such high quality scientific expertise and knowledge.

A major concern to emerge is ownership of the current work in this area. Do we have appropriate structures in place to maintain control over the technology we do develop? In biotechnology whoever owns the core technologies (eg through patents) can have effective control over all applications and their subsequent sales.

However, developments in genetic and biological technologies challenge fundamental aspects of our view of humans and the relationship between individuals and society. This is reflected in the genuine and widespread concerns of people across Australia. The way in which we introduce and develop such technologies must acknowledge this, if we are to realise their potential in the longer-term.

It is important that the S&T community be able to build and enjoy the trust of broader society in the long-term. An important contributor to this will be the ability to address ethical issues in an accountable way and to provide some priority to S&T developments in areas of strong community interest, such as genetic screening. Australia needs to develop a national regime for genetic and biological technologies that is 'world best practice' in its ability to take account of the breadth of issues. This should be supported by appropriate government legislation and regulatory control.

Area for Action: Advances in Biological Technologies

ASTEC considers it necessary to continue building on Australia's international position in genetic and biological technologies, by developing a coherent strategy and regime for the purposeful development and application of these technologies.
This will require an integrated national strategic approach to the development and use of biological technologies in the private and public sectors, and requires the involvement of Commonwealth and State governments in close consultation with industry, scientists and the broader community.

Priority Action for the Commonwealth Government 3

ASTEC recommends that as a priority the Ministers for Science and Technology, Health and Family Services, and the Environment, in conjunction with State governments and other relevant Agencies take action to:

- as a matter of urgency, establish a Task Group to coordinate the development of national guidelines related to ethical, environmental and equity issues arising from biotechnology developments and, in particular, for genetic testing and eventual treatment of humans and the use of personal genetic information;
- ensure the efficient development of new markets for biologically engineered products, by developing agreed national safety regulations and procedures, including product labelling, and seek to establish a suitable regulatory environment across all States and Territories;
- develop and implement temporary support for the creation of effective commercially-oriented networks within the Australian biotechnology research and industry sectors, with a view to identifying and removing impediments to the development and commercialisation of Australian technology; and
- ensure ongoing support for Australian participation in high priority international initiatives, eg the Human Genome Project, and for the development of S&T and biological industry links within the Asia-Pacific region.

Impacts of the Key Forces for Change

ASTEC identified four Key Forces for Change for Australia to 2010. What are the implications of these for Australia?

This Chapter explores the combined impacts of these forces from three points of view: industry, government and the broader community (See Box 7). It examines the role of science and technology (S&T) in managing them in a constructive way.

6.1. Impacts for Industry

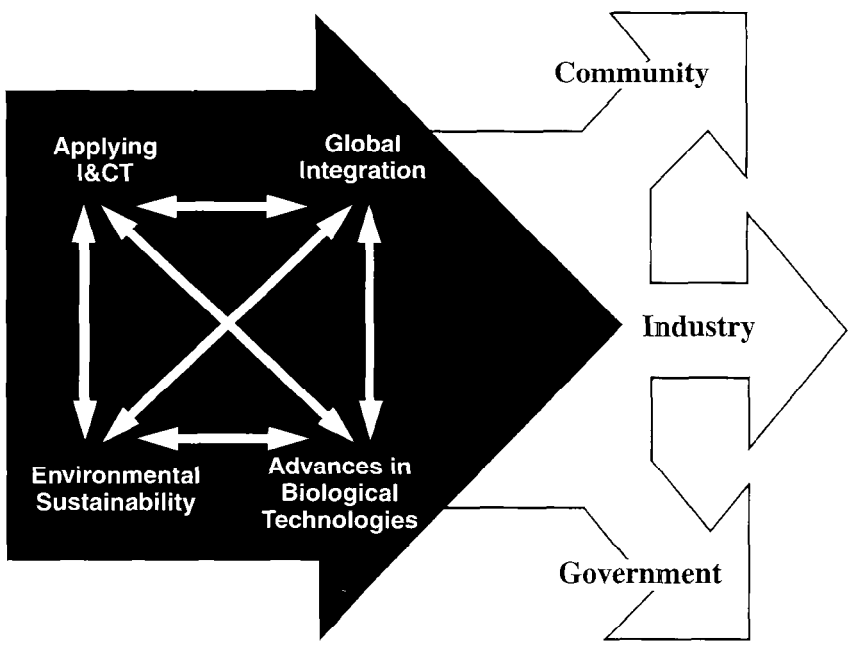
Innovation and the changing rules of competitiveness

As we look towards the future, the rules of competitiveness are changing and we need to ensure that we can respond effectively. Science and technology (S&T) will be an integral part of effective strategies to manage the changes ahead. It is important to consider the specific ways in which S&T can contribute to the achievement of industry goals.

Responding to the new needs and opportunities presented by the Key Forces for Change will require high levels of innovation and entrepreneurship. ASTEC identified a series of emerging challenges for Australia's national innovation capacity to 2010 in order to:

- shape Australia's long-term opportunities;

Box 7. Combined Impacts of the Key Forces for Change



- manage risk and uncertainty;
- grow new businesses;
- support the technologies of tomorrow;
- create infrastructure for national and global networks;
- enhance research and development (R&D) in government enterprises;
- educate innovative managers for the 21st. Century; and
- deliver on regional leadership in 2010.

The immense social and economic transformations associated with the techno-economic paradigm change, arising from the impact of the four Key Forces for Change, can involve:

- new 'best-practice' forms of organisation in the firm and at the plant level;
- new skill profiles of the workforce, affecting both quality and quantity of labour and corresponding patterns of income distribution;
- new product mixes, with new technologies representing a growing proportion of Gross Domestic Product (GDP);
- new trends in innovation (both incremental and radical) as substitution of the new factors occurs;
- new patterns of location of investment, both nationally and internationally, as the new factors change comparative advantages;
- new waves of infrastructure investment to encourage diffusion of new technologies;
- new waves of entrepreneurship and small, start-up firms in new technologies and industries;
- a tendency for large firms to concentrate – by means of growth or diversification – in the new factors; and
- new patterns of consumption of goods and services along with new types of distribution and consumer behaviour.

ASTEC's initial consideration of the relationship between industry innovation and foresight took a broad approach across industry sectors. However, long-term S&T issues and constraints have considerable variation between industries. The issues are complex and impinge on the strategies and possibilities for innovation, the adoption and use of technology and long-term competitiveness. It will be important to adopt at least a sector by sector basis for foresight analysis and possibly adopt a business unit level of analysis. Foresight, used as a means of enhancing competitiveness, requires detailed understanding of the specific technologies and operations within individual firms or industry sectors and of their markets. The development of 'industry foresight' in Australia has great potential to assist innovation by helping managers and planners develop strategies that enable them to 'compete for the future'.[11]

Innovation is an uncertain process, but an innovator needs to be willing to look ahead with confidence to make strategic choices and investments today, in anticipation of uncertain future returns. Foresight explores the critical uncertainties and possible developments in key variables. The approach helps to develop strategies to cope with divergent outcomes and to sensitise an organisation to recognise signals of possible changes in the world, thus enabling quick

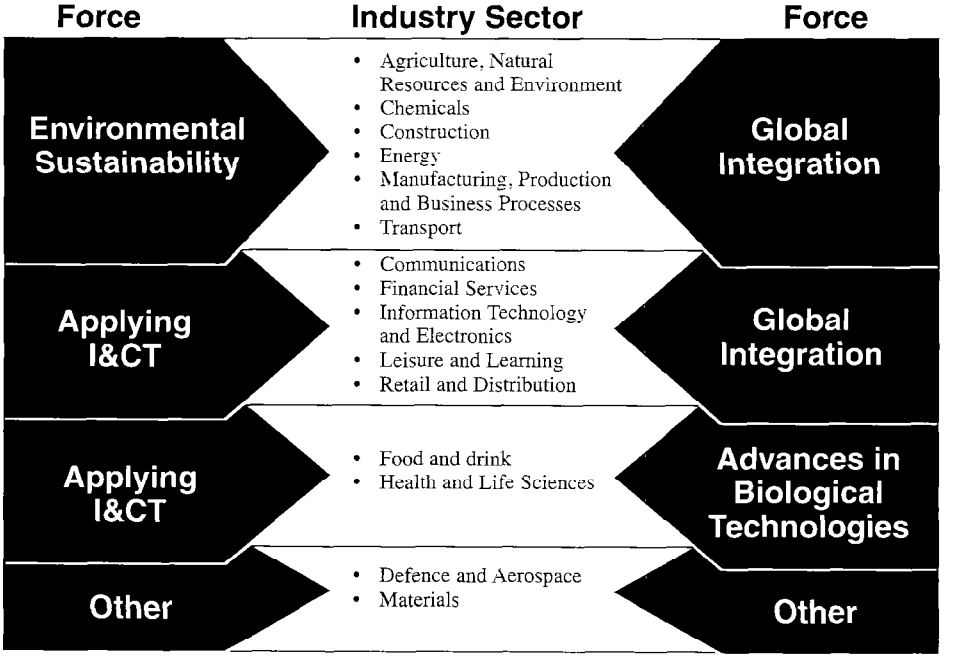
and appropriate responses. Foresight methods can help to articulate the different pathways that might exist for the future. It can help innovators to find appropriate movements down each of these possible paths.

Leaders in innovation in 2010 will be more systematic in their use of innovative techniques. The trend for many will be toward enhanced development, speed and efficiency. This will be assisted by changes in strategy and organisation, including networking between suppliers, customers and collaborators, and integrated data systems such as 'electronic toolkits' to aid design and development.

The Key Forces for Change will have different impacts on various industry sectors. For example, industrial activities which are on a large physical scale, or based on natural resources, are likely to be influenced more strongly by the need for environmental sustainability. That is, a greater impact on mining, agriculture and large scale manufacturing (eg petrochemicals). Of these, biology-based technologies might be more important for Australia's food and fibre based production and value added sectors, whereas improvements in information and communications technologies (I&CT), leading to advanced management systems, could have greater impact on larger enterprises regardless of whether they are resource based.

Advances in S&T will impact on all sectors, but in different ways, as illustrated in Box 8.

Box 8. Dominant Key Forces for Change influencing long-term industry issues



In looking at **drivers** of innovation and competitiveness, the UK foresight study identified four broad groups of industries – defined according to where the principal, although not exclusive, drivers to international competitiveness operate. This framework helps to identify the main strategic research orientation for each sector. The four groupings are:

- *Chemicals, Materials, Defence and Aerospace, and Health and Life Sciences* driven mainly by advances and investment in basic science, engineering, and technology;
- *Information Technology (IT) and Electronics, Communications, Food and Drink and Financial services* driven mainly by an ability to exploit already foreseeable advances in S&T and secure pull-through into internationally competitive products and services;
- *Transport, Energy, Retail and Distribution, and Agriculture, Natural Resources and Environment* driven mainly by the stimulus provided by political, social and regulatory environments; and
- *Manufacturing, Construction and Leisure and Learning* driven mainly by investment in human resources – developing new skills and deepening understanding of business processes and consumer preferences, eg by investment in relevant areas of science, engineering and technology.

Technology 'forecasting', such as the 'Delphi' surveys used in international studies, provides valuable glimpses of the internal dynamics of scientific and technological processes. They identify innovative possibilities experts perceive as realisable over the next 20 to 30 years. Identifying **constraints** to the realisation of potential future developments and innovations is an important feature of foresight work. The UK study reveals considerable variations in the predominant constraints for particular sectors and found four main groups:

- *Economic viability* – this applies to Energy, Communications, Retail and Distribution, Construction and Transport, the realisation of innovations being mainly constrained by, costs or unsatisfactory return on investment. R&D in these sectors might therefore focus on reducing the cost of major investments and of widely replicated technologies.
- *Technical feasibility* – Chemicals, Health and Life Sciences, Defence and Aerospace, Materials, Food and Drink, and Agriculture, Natural Resources and Environment face strong constraints in the realisation of many potential innovations, due to the level of technical risk and difficulty. R&D in these sectors should focus on applied research to solve complex technical problems.
- *Social/ethical acceptability and consumer preferences* – Leisure and Learning, Retail and Distribution, Financial Services, and Information Technology and Electronics face strong constraints from cultural attitudes and pressure groups, where the 'social and ethical acceptability' were considered particularly important. In these sectors,

I&CT is a pervasive driver of change and issues are primarily how to apply it effectively.

- *Industrial and commercial opportunity* – Information Technology and Electronics, Manufacturing, Production and Business Processes, and Construction face strong constraints where competitive circumstances might inhibit innovations. In these sectors, market structures were considered important.

In addition, *lack of funding*, for either investment capital or research funds, is identified as a significant constraint for a fifth group of sectors – Defence and Aerospace, Materials, Health and Life Science, and Transport.

This type of information from foresight analysis can provide a broad context for businesses and help them consider their own longer-term strategies.

A forward-looking approach, which recognises the critical links between foresight and innovation, may be able to reduce some of the risks of innovation. Foresight is not intended to replace more traditional methods of analysis, but to add a new dimension to strategic thinking.

Area for Action: Developing Forward-looking Innovation Programs

ASTEC considers that building competitive Australian businesses into the 21st Century will require a world-class innovation capacity. A long-term perspective on differences between industry drivers and constraints indicates the value of a sectoral industry-driven approach to innovation policy. It is necessary to develop coherent sectoral strategies for encouraging technological innovation and S&T based competitiveness in Australian industry. Actions that might be considered include industry sector consultative boards to initiate 'critical technology' reviews and ensure that relevant organisations across Australia in the private and public sectors have access to outcomes of national and international studies on new and emerging technologies, including foresight studies. Such initiatives might be used to identify strengths, weaknesses and critical gaps in Australia and help develop a strategic framework to investigate and respond to impediments to Australia's future competitiveness and build links between Australian and overseas organisations and industries.

ASTEC also suggests a need to acknowledge and respond to the recommendations of the ASTEC sectoral Partnership studies.

Opportunities for industry

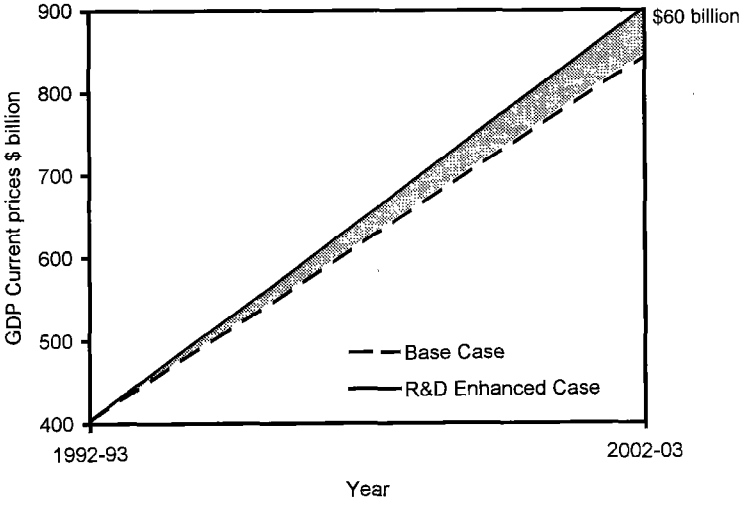
While world merchandise trade is expected to continue to expand at a good pace, the nature of that trade is shifting towards R&D intensive commodities, with trade in these commodities growing much more rapidly than merchandise trade as a whole. Services exports are now growing more rapidly than goods exports, with particularly high rates of growth in travel services and in the increasingly knowledge intensive other non-official services. Much growth over the next 15 years is expected to be in areas managed by government today – health, education, environment and infrastructure.

As part of this study, ASTEC considered the role of S&T in wealth creation and whether economic growth could be lifted through additional investment in R&D. Sheehan, for ASTEC, tested the hypothesis, based on new growth theory, that there is the potential to boost Australia's economic growth through government policy initiatives which facilitate scientific R&D and the transfer of new technology.

The ratios of exports to production, and R&D to value added, have increased strongly in the past decade in high technology sectors of the economy. The strong association between the rises in these two measures provide strong *prima facie* evidence of an important causal link of increased R&D in Australia's strong performance in 'high-technology' exports.[12]

Accordingly if, through a variety of policies, Australia were to increase expenditure immediately on R&D as a proportion of GDP from 1.7 per cent to 2.5 per cent then, over a 10 year period the additional resulting increment to GDP would be about $60 billion (in current prices). This would imply an altered industrial base for the Australian economy from that of 1995 and has vast implications for the economy as a whole (see Box 9).

Box 9. Incremental impact of research and development on the limits to economic growth



Adam, of CSIRO, has suggested that in order to overcome Australia's trade deficit by the year 2000 we will need an expanded industrial economy, based on 10 new $1 billion companies (to act as the strategic business units); 100 new $100 million companies (growing from existing smaller companies); and 1000 new $10 million companies (from start-up ventures).

Using such a framework, the following list of potential candidates was derived by ASTEC from a special round of consultations with industry leaders:

$1 Billion businesses

- Clean green food; cable delivered information and entertainment services; health services training and delivery; transportation equipment; integrated transport services into Asia; applications of mobile telephony; major aircraft maintenance; mineral processing, eg magnesium; gas conversion; services and engineering needs of mining companies; remote sensing; waste management.

$100 Million businesses

- Health technology – products, equipment, screening services; specialised high speed shipbuilding; sporting equipment – technology, facilities design, services, testing, etc.; support services for tourism – software, equipment, training, etc.; Interscan; Membrane filtration; design and manufacture of special packaging, controlled atmosphere containers; food processing equipment; taste – texture–flavour control for food.

$10 Million businesses

- Specialised foods – natural, natives, exotics; specialised software; specialised horticulture; new personal home centred services for affluent individuals.

Our consultations showed that there is a strong emphasis on opportunities in Asia, reflecting a widely held view that the next 15 years will see a maturing of our place in the region. It was noted that 'constraints' on growth in the Asia-Pacific region might represent potential opportunities for Australia. Many are in current areas of Australian strengths including: human capital and skills; infrastructure; resources, energy and its efficient use; and continuing access to developed markets, eg European Union.

ASTEC identified many opportunities for future growth in:

- *Knowledge-based services* such as professional and technical services, information technology services, banking and insurance, travel, modern health care and education. The dominance of service industries in developed countries' economies is expected to continue, with a shift towards exports of services and service-intensive goods. It will become less useful to distinguish between goods and services and between the corresponding sectors of the economy. Manufacturing industry is a major purchaser of services and the service elements of manufacturing may become dominant in determining export performance.

- *'Cultural' exports* in areas such as global multi-media content, education and leisure services and contemporary music. ASTEC found a note of confidence in Australia's ability to add to global cultural development, particularly in providing global media content, multi-media content, and education services, once customer needs are identified. The development of specialist content for broadband services delivery will require S&T support through skills and knowledge, a high general education level and effective infrastructure for business.
- *Tourism and travel* especially from the East Asian and Asia-Pacific markets. Demand is increasing for even greater variety in types of tourism and a need to tailor packages to specific 'special interest' market segments, eg ecotourism. S&T can help to ensure sustainability of tourism growth, especially in fragile environments. Given that one new job is generated for every 17 international tourists and one for every 200 domestic tourists, it is predicted that tourism will generate 200 000 new jobs in Australia over the next decade and generate $20–30 billion in additional overseas income.[13]
- *Infrastructure development* involving public and private sectors eg integrated systems, the development of medical and educational facilities, municipal services, systems for efficient government services (eg taxation, social security or customs technology), mail sorting, mobile telephony, emergency services, environmental standards, stock exchanges, banks, betting systems, film and television. Australia has a well developed infrastructure base to leverage export opportunities, including involvement by many organisations and sectors not conventionally associated with 'exporting'. A variety of government instrumentalities have an ability to market infrastructure development services to other countries, including through collaborative agreements.
- *Resource-linked business*, including supply of raw materials and value-added resource-based products, supported by services and technology for their use, including clean coal. Energy requirements in developing countries are predicted to escalate over the next 15 years, particularly in the Asia-Pacific region. It is clear that fossil fuels, eg coal and gas, will continue to be the major energy source to 2010. In the longer-term, concerns about greenhouse enhanced climate change suggest limits. Australia has strengths in efficient coal technologies and other energy technologies, eg solar and wind power and hybrids incorporating diesel power.
- *Environmentally-friendly technologies* such as clean production techniques, environmental management services, water treatment, air pollution control, solid waste treatment and recycling are likely to continue to be high growth areas into the 21st Century. Markets for environmental goods and services are growing rapidly in Australia and the Asia-Pacific region, with an estimated market of more than $US60 billion by

1998. The ability to apply such 'clean' technologies may be the limiting factor in developing industry sectors in Asia in the future and application of Australian expertise may provide a significant competitive edge.

- *Agriculture* export opportunities are seen as particularly strong in Asian markets, although a focus is needed on customer needs and tastes. Dairy, beef and grain-based products and brands present many opportunities for exports, as does agricultural technology. In the future, agriculture requires a continued diversification into new enterprises and niche markets while maintaining sustainability.

It is critical that those opportunities which have been identified are tested further to assess their potential and Australian industry needs for 2010.

To improve Australia's strengths in engineering, and provide the knowledge base for the expansion of economic activity in areas such as elaborately transformed manufactures and exporting engineering services, will require substantial improvements in the overall performance of university engineering departments, both at the undergraduate level and in research and research training. ASTEC believes that there needs to emerge a small number of world-class engineering schools, capable of producing the high quality graduates that will be needed by industry.

The evolving nature of business at the beginning of the 21st Century indicates that business needs vary and will change. It is important to ensure that the many Commonwealth and State policies and programs addressing industry, eg those of AusIndustry, recognise the varying needs of business, especially those which are small or medium-sized. In the future, there will be an even greater need to look at specific and targeted advice and assistance.

Area for Action: Developing S&T-based Businesses for the 21st. Century

ASTEC considers that there are a range of potential new businesses and markets for the 21st Century that have a significant science, technology and engineering base. There is a need to ensure that Australian businesses are able to effectively use S&T as an integral part of company operations as a means to establish core business growth in future years. A knowledge of international S&T developments and trends in new applications is important to developing long-term business strategies in all sectors.

While it is for the private sector to identify and pursue business opportunities, there is a significant role for governments to provide information about emerging industry and technology developments and to facilitate the exploration of opportunities; and to develop incentives for public sector organisations to undertake R&D and make the best use of S&T.

ASTEC considers that relevant S&T Agencies and industry organisations might

consider actions to collect and disseminate information on emerging characteristics of new businesses and industries, including information on the complex relationships between S&T and economic growth in specific sectors; the development and application of S&T to underpin the export growth in service industries in particular.

6.3. Impacts for Government

The Key Forces for Change are expected to have many impacts on governments. The potential structural impact of globalisation is considerable and leads to questions of how the roles of nation states may change. Traditional regulatory instruments employed by national governments may not be adequate to the task of policing this new world. If national borders become less important then our relationships with other countries, in bilateral and multilateral associations, will become more important.

The environment does not stop at national borders. Concerns about environmental issues are driving bilateral, regional and international agreements on air pollution, land-based marine pollution, climate change, ozone depletion, fishing practices, preservation of the Antarctic, desertification, biodiversity and forest management.

Information and communications technologies are bringing many changes. They are allowing governments to provide services more efficiently with a potentially greater level and range of information. However, the technology raises important longer-term issues of equity and access and impacts on national culture and identity. Governments are interested in fostering the developing information infrastructures and should address access and equity issues. They have a role in developing standards, determining privacy issues, developing legislation on security and considering cultural issues and censorship. They must also consider their own role as an information provider.

Genetics and biological technology have the potential to provide many benefits to Australia, but they are accompanied by many ethical and legal issues. Governments need to continue to develop safe and balanced 'international best practice' approaches to innovations using these technologies.

The government is both a user and a provider of S&T. Many S&T based needs over the next 15 years will be in areas coordinated by government today – health, education, environment, infrastructure. The public sector has an important role in innovation in these areas, particularly through the network of cooperation between producers (industrial firms and public sector research organisations), users (usually other firms) and regulators (at different levels of government).[14]

The public sector also has a role in stimulating demand for sophisticated manufactures and services in areas such as military equipment, telecommunications development and infrastructure provision.

In this study, ASTEC formed Partnerships in a number of areas where S&T can have a significant role in assisting governments to manage change, eg the provision of urban water, national policies for I&CT, and medical research related to aging. For each of these, particular long-term issues gained prominence. For example, governments at all levels need to work together to address issues for the urban water system in Australia, which is undergoing profound change due to a widespread recognition of limited water resources and the need to achieve environmental sustainability.

At present, a high proportion of the infrastructure and services which provide the basis for future growth are provided in Australia by public sector businesses, and some of our best aggregations of commercial and technological expertise are to be found in such businesses.

ASTEC has suggested a review of the potential role of government enterprises in fostering innovation, including through R&D, into the 21st Century. One option would be a public sector business R&D incentive scheme, with features such as:

- a cash rebate of say $1 for every $4 spent on *bona fide* R&D undertaken in pursuit of the business objectives of each enterprise;
- applying the scheme to both public trading enterprises and organisations in the general government sector (excluding any tax paying publicly owned bodies); and
- an annual amount equal to cost of the scheme to be deducted each year from the total funding of public enterprises, according to a formula to be developed.

R&D might also be considered in a wider sphere of government involvement in S&T. For example, ASTEC believes the potential roles of R&D should be explicitly included in all major government programs of micro-economic reform, eg ports and transportation.

S&T has a pervasive but often subtle effect on our society and governments need to consider how S&T can be used in preparing appropriate strategic responses to change. It will be important for governments to have ready access to S&T information and to incorporate a knowledge of the impacts and potential contributions of S&T into policy development and service delivery.

Area for Action: Improving the Input of Science and Technology to Government Programs

ASTEC considers it necessary to develop a more effective input from S&T to decisions by Governments. The greatest challenge however is not simply injecting an S&T knowledge base, but also to effectively integrate a greater consideration of potential contributions from, and impacts of S&T on government decision-making processes and programs in a wide range of areas. This involves not just traditional

'S&T' issues but all those related to a productive economy, eg micro-economic reform, and programs for a stable supportive social fabric.
This will require governments and agencies to enhance their ability to recognise and utilise the potential contribution of S&T (including engineering and R&D) to programs and other decisions and to communicate this information effectively to stakeholders.
There is a need to develop effective mechanisms to ensure science, engineering and technology information relevant to Government objectives is disseminated more effectively to stakeholders (eg S&T, economic, social and resource management information on sustainable development should be made available to farmers).

Priority Action for the Commonwealth Government 4

ASTEC recommends that as a priority the Minister for Science and Technology in conjunction with other Ministers, take action to:

- examine the scope and adequacy of sources of information on relevant science, engineering and technology in Commonwealth Departments and Agencies, and to consider the identification or appointment of S&T advisers, with line management responsibilities at executive level, to contribute to strategic planning and policy development.

6.3. Impacts for the Community

Over the next 15 years, many changes can be expected in a wide range of different aspects of our lives: education, health, shopping, crime and personal security, transport, housing, employment, leisure and sport.

Global integration is expected to bring us much closer to other parts of the world and our span of friends may be generally global, communicating regularly through the Internet. But this development may have the effect of diminishing the closeness and cohesion of the local community. It may even challenge the very nature of 'Australian-ness', not only in terms of national companies and brand names (eg Vegemite), but in the nature of our own culture.

The implementation of ecologically sustainable development, with consequent changes to attitudes, education regulations and further introduction of environmental costing, would also lead to changes. For example, it could encourage further recycling and the replacement of rubbish tips with long-term material storage. Full costing of water could lead to dual water systems in most homes, the rise of xeriscape gardening and the introduction of water tanks attached to private houses. Increased energy prices could lead to the wider use of solar power, collected and used on a household basis, and increases in the

cost of private cars leading to the need for changed patterns of urban transport and development.

The revolution in I&CT will impact on the home (and home-based small business) giving access to a level of computing power once sufficient for large corporations. The mobile personal telephone is expected to have replaced the fixed-station telephone and to be used more for data transmission and video links. Compression of data and capacity increases are expected to make the video phone a practical proposition. The expansion of TV channels will continue, so that the structure of the broadcast media becomes much more akin to the structure of the print media: a few national and international products, but a multiplicity of special interest channels, the equivalent of specialist magazines.

It is possible that, by the 21st Century, less than 50 per cent of the workforce will be in conventional, full-time jobs and that there will be growth in self employment. This change will necessitate a fundamental rethink of the traditional concepts of work, job and career and will impact on issues such as family support and the organisation of firms. It is expected that an increasing proportion of the available jobs in our community will require high order intellectual rather than manual skills. This has major implications for the education system, as well as for the credentials that young people are expected to acquire prior to seeking employment. The tendency for women to re-enter the work force is set to intensify, which has implications both for the way in which organisations are run and for the structure and support of the family.

We can expect to experience a commercialisation stage of the biotechnology revolution. Mapping of the human genome is likely to have reached the point where information can be available about our pre-dispositions to certain diseases. To whom should this information be made available? We may also be able to purchase genetically modified food that has nutrients added to prevent the onset of certain diseases.

There is little doubt that S&T promises much for the future – greater convenience, longer life and improved access to services and products. S&T will be an essential part of developments which could improve our lives.

At the same time, the community might reject some aspects of the future that are inconsistent with their expressed goals for Australia in the 21st Century as a creative, productive, inclusive and ecologically sustainable society. Society is able to influence what technologies are adopted and diffused. For example, the realisation of a number of developments in the Japanese Delphi technology forecast survey were seen to be constrained by consumer demand, particularly social/cultural issues, including:

- fully fledged medical manipulation of genetic disorders;
- new plants, produced through gene manipulation, widely used as food;
- routine performance of organ transplantation;

- perfection of systems to lengthen organ preservation, enabling world-wide supply of some kinds of organs for transplantation;
- widespread home office work based on advances in video telephones, on line computer system and facsimile; and
- widespread use of an independent sociability training system, designed for groups of children of different ages, enabling them to be trained in social interactions.

One important issue is whether the benefits of developments in S&T will be shared equally across the Australian community. Australian society comprises many different groups. Our large land area, scattered population, multicultural society and large regional centres raise particular issues.

Significant changes are expected in the make-up of the Australian population. While Australia's population will be aging, this will not impose as dramatic an impact on Australia as other developed countries, such as Japan. There is expected to be an increasing number of Asian Australians and a greater diversity in the source of countries for immigration. The number of Aboriginal and Torres Strait Islander people is expected to increase slightly, although there is still likely to be a gap between their situation and that of non-indigenous Australians.

It has been suggested that the aging population will lead to conservatism in politics and pressure to cut public spending. An influential 'older Australia' might be expected to seek lower rates of inflation, unemployment and crime, and have a much lower tolerance of disorder and anti-social conduct, with a greater acceptance of authority in controlling behaviour. A continuing, if uneven, decline in gender inequality will occur.

Most young Australians see themselves embracing technological change more readily than previous generations, but some question the benefits and feel that the rate of advancement is getting out of hand; for example, technological advances should not be used to replace jobs but as a tool for facilitating more productive work.

Young people are particularly concerned with the social context of S&T – how it might improve or reduce our capacity to realise our goals as a nation; who will make decisions on priorities for S&T; how governments allocate funds to S&T; and related ethical issues. They argue for more consideration of human needs – funds would be better spent on solving problems such as poverty – and are concerned at the use of S&T to further entrench wealth and power.

There is a widespread view that isolated communities have gained relatively little from S&T. Opportunities for these communities are considerable, if the potential of I&CT developments – telemedicine, distance education, employment at home – is realised. But so are the costs.

I&CT-based services have certain traffic pre-requisites for effective operation and often these are based on urban requirements and standards. An analysis of locational disadvantage of remote communities indicates the benefits of the city are often only sustainable through the adoption of

urban lifestyles. To re-create these conditions for small communities can undermine the rights and abilities of these residents to establish their own priorities and standards.

Aboriginal and Torres Strait Islander communities in isolated areas highlight some aspects of community concerns about increased levels of S&T. The fostering of independent technical advice, through non-government organisations, to provide grass-roots input to technical decision-making is one means of ensuring greater control of service provision by communities, while at the same time resourcing communities with expertise responsive to community aspirations. Establishing a network of technical resource centres which concentrate their attention on the specific problems faced by Aboriginal and Torres Strait Islander communities has been suggested.[15] A longer-term alternative might be to develop this infrastructure within Aboriginal and Torres Strait Islander communities.

Area for Action: Developing Technological Literacy in Aboriginal and Torres Strait Islander Communities

ASTEC considers that S&T offers much promise in promoting wealth generation and improving community well-being. It is important to ensure that the benefits of developments in S&T will be shared across Australia's many metropolitan and regional centres and rural and remote communities. To develop the critical role of S&T in the Australian community will require attention to all areas. An immediate area of action is the capacity of Aboriginal and Torres Strait Islander communities to access infrastructure to develop, undertake and evaluate appropriate S&T.

Priority Action for the Commonwealth Government 5

ASTEC recommends that the Minister for Science and Technology and the Minister for Aboriginal and Torres Strait Islander Affairs:

- consult with Aboriginal and Torres Strait Islander communities, particularly in isolated regions, about their capacity to access infrastructure to develop, undertake and evaluate appropriate S&T; and
- explore options for developing infrastructure programs similar to those for health and education, where there is a local indigenous technology innovator, reviewer and adviser to communities, or adviser-consultants attached to specified tertiary education institutions.

chapter 7

Implications for the Science and Technology System

7.1. A Science and Technology Culture

In the 21st Century, wealth creation, social well-being and the health of our natural environment will increasingly depend on the science and technology (S&T) system, as a vital part of the 'knowledge economy'. What changes are needed to improve our S&T system for the world of the 21st. Century? What are the critical priorities for technology and skill development? How can we build effective linkages to the community?

The 20th Century has seen an explosive growth of knowledge and information, generated by modern scientific research and its technological application. S&T have contributed to the increase in our material well-being to an extent that is unequalled in any other period in history. The insights gained through science and our improved understanding of nature have contributed fundamentally to the shape of our culture and society.

However, this study has identified a number of important changes required in the Australian S&T system to meet the challenges of the 21st Century. There is a need for Australia to integrate into the global S&T system. There is a demand for more effective linkages within the S&T system and with other systems and a need for the S&T system to better reflect changing community values.

To benefit from opportunities in the 21st Century, S&T will need to be far more deeply embedded in our Australian culture than it is now. Challenges such as genetically modified organisms, global information flows and medical breakthroughs will need to be matched by national scientific and technological literacy, a commitment to underpin national investment in research and technology and a sophisticated national debate which values social, economic, environmental and ethical concerns.

The next century requires an S&T community that is more aware of, and responsive to, community concerns. It must meet the community half-way in considering the credibility of other perspectives.

Area for Action: Building a Context-aware Science and Technology System

ASTEC considers that, as a vital part of developing a 'knowledge economy', it is necessary to promote an S&T system that is highly integrated into its social and industrial context, and, while committed to excellence, is open and responsive to priorities arising from strategic industrial, social and ethical issues.

To help meet Australia's future needs in the 21st Century, we need an effective S&T system which both reflects and contributes to shaping, community values and economic progress.

ASTEC suggests that industry, funding agencies, professional bodies and others need to consider the preferred directions for publicly funded research in Australia and ensure that mechanisms to establish priorities in strategic research reflect the frontiers of knowledge, industry needs and community concerns.

It will be necessary to implement effective mechanisms to ensure on-going and effective two-way communication between S&T experts and the community and in particular to address the low participation of young people, especially women, for example, through volunteer participation in S&T activities (eg Waterwatch).

7.2. The Information Base for Research Decisions

Australia has strengths and weaknesses in relation to 'critical' technologies. In general, Australian science is well positioned for health and medical, biological sciences, earth sciences and agriculture. It is not as well positioned for other areas, although there are niches of high performance.[16] Should we give priority to building on strengths or to reducing our weaknesses? Should we seek to build our science in areas where we have strong technological capacities or vice versa?

The issue of priorities and targeting on strengths is an issue being debated in many countries around the world, not just Australia. The UK chose to identify 'generic' priorities at a high level to guide their S&T decisions, whereas the Japanese disseminate information about developments for others to act upon. The attributes of a critical technology vary between organisations, just as information on critical technologies will be used in different ways. Broad knowledge of critical technologies can help decision-makers in a range of areas – in both industry and government.

In an increasingly global world, this type of information can be used for competitive advantage and it will be important for Australian organisations to have access to it. Government can provide information to assist the range of decision-makers to consider the outcomes and implications of

critical technology exercises conducted overseas. Government can also facilitate Australia's involvement in a range of international critical technology exercises.

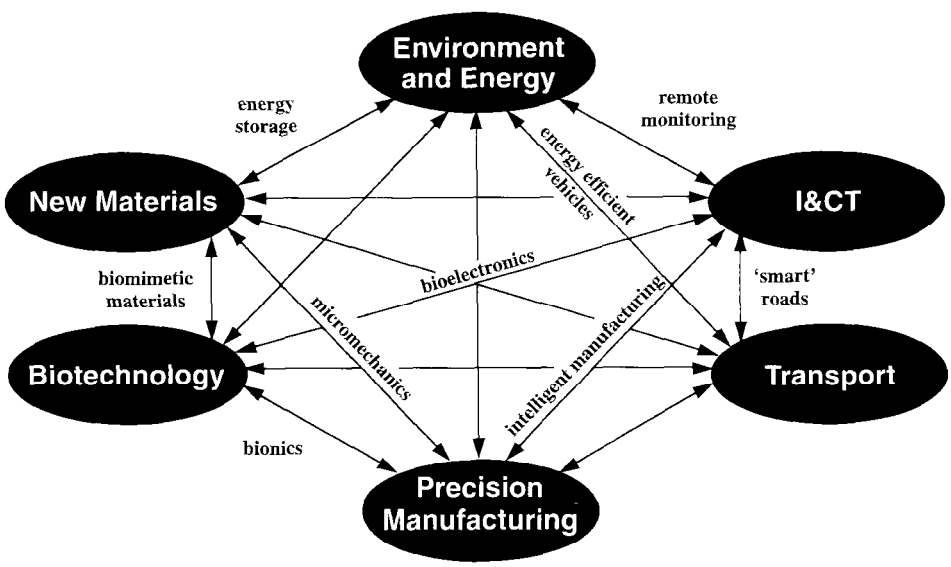
International foresight studies identify many potential future technologies. These studies suggest that the dominant new technologies of the 21st Century will be those that combine knowledge from different fields – an integration of what used to be separate branches of science. Exciting new areas are already emerging in photonics and nanotechnology, with potential applications such as molecular-scale electronics and bio-sensors.

In some studies, assessment criteria are applied, for example, for a technology's potential contribution to wealth creation or community well-being, and particular technologies are then identified as 'critical' in the areas of:

- environment, including energy;
- transportation;
- information and communications technology and electronics;
- genetics/biotechnology;
- manufacturing/precision and control in management; and
- new materials.

There appear to be many cross linkages between technology areas – such as between precision management and information and communications technologies (I&CT), for 'intelligent' manufacturing systems (Box 10). It may be possible for Australia to use its strengths in one area to facilitate developments in another, perhaps weaker area.

Box 10. Some examples of links between broad critical technology areas



Managing and exploiting such multi-disciplinary technologies will present new challenges for research and industry. A good deal of effective multi-disciplinary research is being performed, but there are problems in giving adequate recognition to emerging areas of S&T, particularly when these do not fit easily into existing disciplines.

Tapping into new knowledge, through networks, will be particularly important in inter- and multi-disciplinary projects in emerging technology areas. There are many barriers and boundaries within the S&T system that divide one group from another. Yet the new areas of discovery are frequently precisely at those intersections. Boundary-spanning work must be encouraged and monitored. This may require new mechanisms and structures.

Australia appears to have a limited capacity to maintain an overview of emerging technologies and to put in place longer-term technology programs to ensure that Australian firms are well prepared to take advantage of new technological developments. A long-term view will influence both our ability to take up technology developed overseas and to progress emerging technologies in Australia.

This perceived 'market failure' is seen to be partly caused by Australia's lack of:

- firms that are able to think and act with a long-term perspective on technology, in contrast to many Japanese, US, European or Korean firms;
- information available to firms and researchers about promising and new areas;
- organisations and infrastructure able to help develop and disseminate such information; and
- a world-class research and education capacity in innovation and innovation policy.

There is no specific provision for long-term research on critical technologies in the current S&T policy mix. There is a need to consider public support for investment in co-operative public/private ventures, designed to attain national competence in emerging technologies likely to be important for future economic growth or community well-being.

Australia must position itself to capture the potential opportunities provided by critical technologies and combinations of emerging technologies. It is imperative to continually consider, assess, evaluate and speculate about future technological developments. Whether or not Australia is the major developer, we need to have a 'place at the table' when these important emerging technologies are being commercialised. Many of the technologies of tomorrow will not be developed in one country, but across national borders, thus emphasising the importance of global links.

This suggests an approach based on building on the distinctive strengths of the country in basic science and projecting forward from particular activities in which we have an identifiable comparative advantage, to consider possibilities, not necessarily clearly evident at this time, for developing into the fields deemed to be 'critical' elsewhere.[17]

Area for Action: Enhancing the Information Base for Research Decisions

ASTEC considers it necessary to develop mechanisms to review emerging research and technology areas and assess Australia's strengths and weaknesses in critical technology areas, including evaluating potential barriers to multi-disciplinary research and new collaborations.
There is a great deal of information about emerging technologies, and the strength of the research fields that underpin them, that now may be brought to bear in a more systematic fashion to shape, in the broadest sense, decisions of focus and research allocation amongst the scientific community and research funders. Moreover, the purposeful exploitation of knowledge boundaries has been shown to be highly effective.
ASTEC considers a priority is to introduce, without threatening either the strength of the basic research system or the integrity of peer review processes, more purposeful and better informed mechanisms for shaping the context within which research decisions are

Priority Action for the Commonwealth Government 6

ASTEC recommends that as a priority the Minister for Science and Technology take action to:

- commission a review of Australia's relative strengths and weaknesses in emerging 'hot spots' in research and technology, and commercial prospects into the 21st Century, involving representatives of the Academies, leading researchers, and industrial research organisations; and
- review barriers to the development of inter- and multi-disciplinary research, including funding processes and investigate mechanisms to encourage inter- and multi-disciplinary S&T, including through innovative course design (eg Science-Arts) or funding.

7.3. Integrating into a Global S&T System

Australian S&T needs to adopt a dynamic perspective which takes account of complex changing relationships with countries around the globe. Some of the key challenges over the next 15 years will be to:

- develop a balance between local, national, regional and global orientations in Australian S&T agencies;
- contribute to developing an effective regional S&T policy in APEC;
- manage traditional links with the larger economies of Europe, Japan and the US; and

- strengthen links with growing countries of this region and the Pacific.

This will require us to address, in many different fora, a complex range of issues from intellectual property to education and training. If we want to capture potential opportunities and aspire to regional leadership in S&T we must be prepared to turn rhetoric into action in terms of government support, industry links and cooperative policy development. This requires a coherent and flexible management strategy, developed jointly with industry.

Almost paradoxically, a 'global world' is not necessarily an homogenised world. Regional and local strengths can create nodes of excellence that transcend national boundaries, such as is currently evident inside national borders. Such a world will be based on highly sophisticated understandings of comparative and competitive advantage.

Australia's S&T strengths include higher education and training capabilities, a strong basic research capability and a culture which places emphasis on flexibility and practical problem solving. This provides a critical base for expanding Australia's involvement with the region.

In an era of free trade and 'open regionalism' between countries there should be the confidence to specialise and focus on those areas of comparative advantage. A fundamental characteristic of techno-globalism is building alliances as part of a networking strategy. This aims to facilitate access to knowledge and markets around the world.

There is a potential complementarity of Australian S&T with Asian nations. Australia's strengths in Biological, Earth and Environmental sciences are in areas where Asia is relatively weak, while those in which Australia is less specialised, Physics, Mathematics, Chemistry and Engineering, are the central focus of the emerging systems in these countries. This suggests that there is room for extensive mutually beneficial cooperation between Australia and the countries of East and South Asia in the future development of basic science.[18]

A new perspective on national benefit criteria that takes account of rapidly changing S&T, global developments and the Key Forces for Change will be important. The concept of 'critical' technologies has been used by the US Government to ensure it remains at the leading edge of developments in S&T across all sectors. This is consistent with concerns about 'national' sovereignty and the paradigm of nationalism. However, this study suggests that this paradigm could change.

Global Integration provides a new perspective with which to view national decisions on S&T and which requires the reconsideration of 'national benefit'. Recently the Industry Commission found that the average social rate of return from R&D was around 100 per cent. ASTEC is concerned that we should not succumb to a narrow interpretation of 'national benefit'.

To the extent that increased carriage of Australian funded research in other countries gives rise to spillovers in those countries, it is important to consider the nature and extent of other longer-term (including indirect) national benefits accruing to Australia. These could come from additional downstream applications, industrial and other (eg cultural/trade) links that might consequently be developed. A difficulty is establishing the exact nature of these potential benefits in advance – thus the question of whether criteria can be used to preface involvement. These might include criteria related to issues such as intellectual property, commercial rights, education and training and equipment provision.

Area for Action: Implications of Globalisation for the Science and Technology System

ASTEC considers it necessary for the S&T system to develop an effective response to global integration by adopting a dynamic perspective which takes account of complex and changing relationships with countries around the globe.
S&T can play an important role in developing bilateral and multilateral relationships and in fostering downstream commercial and industrial interaction.
Yet there are risks in loss of intellectual property or from structural factors which limit the economic return to Australia.
An effective response to Australia's increasing integration into the global S&T system over the coming decades will require a more sophisticated understanding of national benefits and periodical review of what is 'in Australia's best interest'.

Priority Action for the Commonwealth Government 7

ASTEC recommends that as a priority the Ministers for Science and Technology and Trade take action to:

- establish a review to assess existing 'national benefit' criteria for Australian involvement in international science, engineering and technology activities, and for foreign investments in S&T in Australia; and
- evaluate Australia's ability to provide relevant and timely scientific and technological information to support Australia's strategic needs in international negotiations, eg for agreements on trade, the environment and non-tariff issues.

7.4. Science, Engineering and Technology Skills

A country's competitiveness into the 21st Century will be increasingly dependent on the skills of its population, which will be made more vulnerable by the operations of a global labour market for highly skilled people, such as S&T specialists. As the level of technological sophistication increases, many more jobs will have an S&T component. S&T skills will be needed not only within the S&T system but also more broadly across the community.

Australia needs to ensure that we do not undervalue engineering and science skills. Our skills development should focus on the concurrent development of technology and 'non-technology' skills, to ensure that the utilisation of technology and opportunities for further skills development are maximised. The required skills can be grouped as:[19]

- *theory skills*: cross-disciplinary skills in I&CT, materials and environment;
- *practice skills*: the way work is performed and knowledge is integrated into production, including manufacturing, resource management, environment and cultural issues;
- *management skills*: people management, finance and economics, total quality management, ethics and law; and
- *personal and interpersonal skills*: needed to facilitate team-work and develop staff and include leadership, communication, time management, creative and planning skills.

For the Australian S&T system to be adaptable, and to manage change effectively, places an emphasis on organisational systems and the development and enhancement of skills. In particular, skills in management, international relations, risk analysis and I&CT will be vital.

A survey of Australia's major customers in the Asian region rated Australian managers a long way behind five 'competitor countries' on key measures of entrepreneurial skill.[20]

Currently, many leading edge organisations are trying to define a preferred vision for effective organisations in the 21st Century, and flexible, dynamic and inter-connected networks are seen as an important part. This creates challenges for developing Australia's skills base to form and reform networks, whether from inside research institutions, or as external and international links.

Networks provide opportunities for governments to encourage innovation through inter-firm and institution-firm linkages. As 'self-organising' systems, networks can diffuse and modulate policy once it has been accepted, so that the task of the government becomes one of helping to construct and maintain networks and of designing robust and flexible policy which can be effectively adapted and used through networks.

Risk analysis can be separated into four interrelated, and often overlapping, steps: risk assessment; risk perception; risk valuation; and risk management. ASTEC believes that well calculated decisions about risk require an adequate information base, including information about predicted,

preferred and possible futures. R&D decisions taken with a strategic view on creating future competitive advantages and effective innovation will be critical to Australia's success in the future. The high risk in *not* having such a strategic approach needs to be continually reiterated and publicised.

The effective interaction of the S&T system with other social institutions is a critical factor in helping Australia to benefit from the forces of change. Some of the biggest issues in S&T will be at the intersection of the financial, legal and S&T systems. A common view identified by ASTEC is that the finance sector considers itself unable to judge the prospects of success for S&T related projects, or of survival for the firm as a whole, so that S&T-based firms cannot attract investment capital. Traditionally, more weight is given to indicators of current or past profitability than to information bearing on long-term prospects. This is generally not due to indifference about long-term prospects but to a lack of necessary information or the capacity to evaluate it.

Skills are required which combine expertise and knowledge from diverse areas such as S&T and financial, legal and intellectual property. Developing these skills may require new institutional mechanisms.

In addition to 'generic' skills, there are many specific skills needed in particular regions or sectors. These can be illustrated by international foresight exercises. In Japan, fostering and securing human resources emerged strongly as a constraint in the fields of Life Sciences and Environment.[21] The UK foresight study identified a consistent theme of the need for new I&CT skills in the existing workforce, and of teachers and students. The UK study gave highest education priority to 'training the trainers', particularly in the fundamentals of mathematics and physics, as a way of achieving change. Manufacturing, construction and leisure and learning sectors in particular were identified as requiring investment in human resources to develop new skills and deepen understanding of business processes and consumer preferences.[22]

ASTEC's Partnership studies also identified a wide range of skills needed in their sectoral areas – for example, the Urban Water Partnership highlighted inter- and multi-disciplinary S&T needs for developing a 'whole systems' approach. They also identified a need for universities and Cooperative Research Centres (CRCs) to better integrate the skills needed in planning, engineering and ecology programs into their courses for professionals working in the urban area. The I&CT Partnership identified the need for a broad base of skills related to digital technologies to provide the needed flexibility to meet changing directions in the industry. The Health Partnership on neuro-degenerative disorders (NDDs) identified the need for a higher priority to be given to gerontology and aging skills development in medical schools. The Youth Partnership identified the need for young people to develop skills in media analysis to make sound judgements based on information obtained from different parts of the media, including the Internet.

Also, some specific skill needs were identified through Key Issue Roundtables. For example, the need for a core of people who have the skills to put genetic technology into practice, eg multi-disciplinary clinical genetics skills, skills in natural resource management, particularly in managing the localised and downstream impacts of a mosaic of intensive agricultural production within a framework of ecologically sustainable development, and skills to enable informed community discussion of highly contentious issues taking into account S&T, environmental and socio-economic perspectives.

Area for Action: Developing Skills for Tomorrow

ASTEC considers it necessary to ensure that our scientists and engineers are capable of meeting the challenges of a 21st Century organisation. This will require an effective response from all organisations currently responsible for the education, learning and on-going development of people who are at present in these areas or who may seek future employment there.

ASTEC recognises the significant amount of training currently being undertaken, but has identified the need for a specific futures orientation, in particular to encourage organisations responsible for S&T (including industry, government, and relevant academies and professional organisations) to review how well they are building generic skills for managing change into the 21st Century. Such reviews, of course, would not be limited to the 'generic' skills identified by ASTEC, but extend to those identified as a priority for an organisation and take into account the appropriate balance between specific S&T skills and more generic skills.

A Culture to Manage Change into the 21st Century

8.1. Embedding Science and Technology in Australian Culture

The world is changing in profound ways into the 21st Century. These changes have the potential to enrich our lives and help us to achieve our national goals, yet they also threaten many things we cherish. We should not underestimate their power, nor the value of tools, such as foresight, to help us manage the uncertainty they present.

Science and technology (S&T) are critical drivers of these changes. They also offer the best hope of meeting the challenges ahead. We need to be more skilful in using S&T to help us shape the future.

An improved understanding of socio-cultural, economic and environmental contexts can better position S&T to help us meet a range of future needs. At the same time, the community requires a better understanding of the capacities of S&T so that it may play a more central role in decision-making.

Many other countries and organisations are engaged in developing skills to consider the future as part of their strategic planning processes. For industry, these skills can provide opportunities for wealth creation as the rules of competitiveness change. For government, these skills can highlight the need for changes in role as new challenges arise.

Australian industry requires a community with a better understanding of S&T to provide a labour force with more adaptable skills and the flexibility to deal with on-going rapid technological change. An S&T literate community was identified as essential for investment in new and technologically high value-added industries. It is therefore critical to innovation and wealth creation. Customers, who demand increased performance through S&T, are also a vital driver for industry to develop innovative ideas.

S&T research can be hindered by community concerns often based on a poor understanding of S&T. Some of the most difficult and contentious issues our society is facing today, such as euthanasia, nuclear power, or biological control agents, could be assisted by a better understanding of the S&T involved in such issues.

The greatest benefit of a broad community understanding of S&T is the extent to which it could assist us to deal with the challenges ahead. New technologies can reduce the levels of disadvantage experienced by different groups. They can also provide targeted responses to environmental problems and suggest new innovations for industry. In our daily lives, a greater knowledge of S&T could give us a better understanding of our working conditions and change our decisions as consumers.

The community's need to understand S&T, its S&T literacy, has changed dramatically over time. We deal every day with a range of things we do not understand, such as digital phones and microwave ovens. Understanding how technology works to enable 'running' repairs is no longer a priority for most people. In the future, our technological literacy is more likely to be a reflection of our ability to feel comfortable using technologies while not understanding them.

Given current community needs, S&T must be set in a broader social context, include a consideration of ethical, equity and access issues and be focused on the crucial role of improving both individual and community decision-making, based on a better understanding of S&T. (See Box 11).

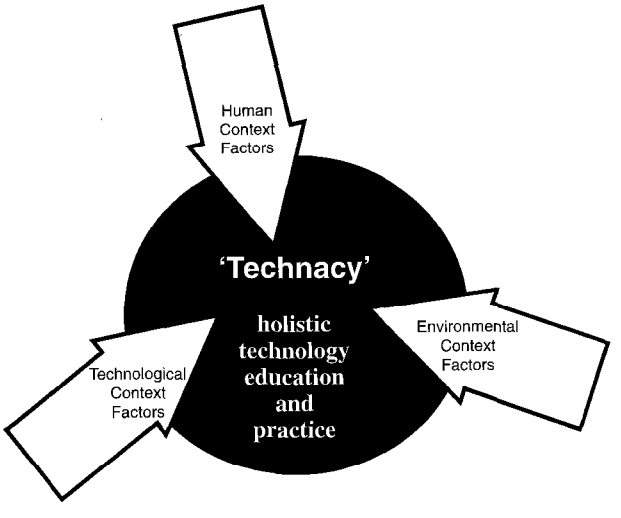
We need an S&T literacy (or 'technacy') that will allow us *inter alia* to:

- use S&T effectively in decision-making processes;
- discuss and adapt new S&T developments;
- appreciate science as part of our culture;
- maximise the benefits of S&T in our daily lives; and
- build strong S&T systems and expertise, including an educated workforce.

For many years literacy and numeracy have been the cornerstones of western industrialised education. Yet there are basic skills in technology and problem solving which are required to support a technological lifestyle. ASTEC considers that technacy provides a sound framework for developing a new vision of the role of the S&T system in achieving national goals and improving understanding of S&T in the Australian community.

S&T education needs to be better integrated into the curriculum at all levels as a skill for living. The education system needs to develop analytical skills so that as a new issue arises people are able to deal with it

Box 11. 'Technacy' – holistic technology education and practice



sensibly. The skills of judgement and discretion in selecting information should encourage curiosity and learning, rather than just passing exams.

The community needs to understand the broader concept of technacy, which incorporates social, environmental and S&T aspects, and encouraged to use it to ask questions and make decisions about S&T issues. However, we must also become more adept at understanding how S&T can resolve our economic, social and environmental challenges in the 21st Century.

While education is the crucial step to achieving change, this is not expected to be fully effective by 2010. Instead, the media has the critical ongoing role in providing information on S&T throughout our lives. It will be important for the media to provide an appropriate context for complex decision-making.

Ensuring S&T literacy and access to technology for a range of groups: young children and their parents, older people from a less technological society, business particularly small and medium businesses, decision–makers in government and the S&T community itself must be recognised as a central issue to the S&T process.

Area for Action: Improving Science and Technology Skills in the Community

ASTEC considers it essential to integrate the role of S&T in economic, social and environmental decision-making into the 21st. Century. This will require a greater community understanding of the role of S&T in society, which in turn will require improved S&T skills learned from childhood.

'Technacy', the technological equivalent of literacy and numeracy, is defined as competence in S&T problem solving that develops the ability to integrate the human, social, environmental and technical aspects of technological issues or initiatives.

Priority Action for the Commonwealth Government 8

ASTEC recommends that as a priority the Minister for Science and Technology and the Minister for Employment, Education, Training and Youth Affairs, work with State and Territory governments to:

- incorporate 'technacy' in primary and secondary school curricula and teaching practice across Australia.

To initiate this process, ASTEC has proposed a study on primary S&T education, which would review the work done in preparing the statements and profiles for S&T and suggest any changes needed to achieve this objective.

8.2. Identifying strategies for science and technology to 2010

The ASTEC study has several unique features designed to test the limits of foresight. We were interested in the extent to which foresight could be used to view future needs through a broad social context. The importance of a demand-driven perspective was clear from theoretical studies and analysis of international experience, yet has proven to be a very difficult task in practice. This is particularly important for 'small' countries like Australia.

Our study was pragmatic, in its selection of areas to study and choice of methodologies. Prior to this, national foresight in other countries had generally been conducted on an economy-wide basis at considerable cost. As this comprehensive approach was beyond ASTEC's resources, we chose to combine a broad cross-sectoral overview, with a small number of more detailed sectoral studies. We used overseas studies to provide information on potential global developments in S&T.

The study is characterised by an open, consultative and iterative process, which was necessary to develop a broad picture of future needs for Australia in 2010. The credibility of the study rests on its ability to accurately reflect the diverse opinions of all Australians – government, industry, S&T experts and the broader community. Many of these contributions were from people and areas not traditionally perceived to have a direct interest in S&T.

We can confirm the findings of other foresight studies that much of the value occurs through the process, represented by 'the five Cs':[23]

- *communication* – bringing together disparate groups of people and providing a structure within which they can communicate;
- *concentration* – encouraging individuals to concentrate seriously and systematically on the longer-term;
- *coordination* – enabling different groups to co-ordinate their future S&T activities;
- *consensus* – creating a measure of agreement on future directions and research priorities; and
- *commitment* – generating commitment to the results among those responsible for translating them into research advances, technological developments and innovations.

To these we can add a sixth, *'comprehension'* – the understanding of changes occurring in businesses or professions, at a high level.

In a similar vein, the Australian House of Representatives Standing Committee on Industry, Science and Technology recently concluded that:

'the Australian Government should closely study the various foresighting methodologies and the experience of other countries with them. There is a need for Australia to use such studies to help provide better direction to research and development (R&D) investment in both the private and public sectors. Foresight analysis has the potential to greatly enhance Australia's innovation

performance. The information and analysis provided by a foresight program is essential to the decision-making process that allocates resources between competing interests.' [24]

The Committee recommended that the Government make a commitment to introduce technology foresight following the completion of the ASTEC study, to adequately fund such analysis on an on-going basis and to disseminate the findings widely to industry and research institutions. They also argued that technology foresight should involve a high level of consultation with industry, researchers and community groups.

Overseas, foresighting activities are considered important to current research and future developments in various areas, and countries are seeking to obtain a competitive advantage by systematically considering the future. We must ensure that we are aware of such developments.

Australia has special priorities and expertise not developed elsewhere and these must be taken into account. Systematic consideration through foresight, taking account of the past, the present and the future can help ensure that we take a realistic approach to building on strengths and meeting our future needs, including making the best use of all available technology.

Managing and adapting to change can be a difficult process. Foresight helps people to understand the nature of change and to place it within a comprehensible framework.

Area for Action: A National Program of S&T Foresight

ASTEC considers that foresight can help provide better direction to R&D investment and has the potential to greatly enhance Australia's innovation performance. The information and analysis generated by foresight can contribute to more effective decision-making and resource allocation.

To build a national capacity for foresight will require a broad ranging program facilitated by the Commonwealth Government, particularly in the initial development of a skills base and the provision of infrastructure. Government, industry, research and educational organisations, professional societies, peak bodies and community groups will need to be encouraged to undertake, or be involved in, foresight exercises.

ASTEC suggests that to carry foresight forward, support will be required to:

- *develop expertise and a skills base in foresight and to provide expert advice on the conduct of foresight studies;*
- *disseminate widely the outcomes of international foresight studies to relevant organisations in Australia; and*
- *promote discussion of the implications of foresight for Australian industry, the economy, society and research.*

Each body must make its own decision about the extent of its use of the foresight process in its strategic planning and organisational development, and what management actions should follow. However, there is great value and importance in ensuring that the learning and the outcomes, are more widely shared. This could be reinforced by requiring all government and publicly funded organisations to report on their strategic plans and the use and outcomes of foresight analysis. Secondly, an annual forum could be established, as a mechanism for dissemination of learning and encouragement for the adoption of foresight processes.

Notes

1 Joint ASTEC-CSIRO commissioned study: Sheehan et al. (1995), 'Australia and the Knowledge Economy: An assessment of enhanced economic growth through science and technology', Centre for Strategic Economic Studies, Victoria University of Technology, Melbourne.

2 Outcomes of ASTEC's Youth Partnership are provided in: ASTEC (1996), 'Having our say about the Future – Young people's dreams and expectations for Australia in 2010 and the role of science and technology', AGPS, Canberra.

3 ASTEC commissioned study: Bourke, P and Butler, L (1995), 'Recent Foresight Studies: Implications for Australia', Performance Indicators Project, Australian National University, Canberra.

4 Australian weakness in areas related to advanced industry is suggested by other recent studies, eg Department of Industry, Science and Technology (1996), 'Australian Business Innovation: A Strategic Analysis', AGPS, Canberra.

5 An analysis and collection of long term strategies is provided by: Economic Planning Advisory Committee (1994), 'Ambitions for our Future', Conference Report 3, AGPS, Canberra.

6 An overview of the principles and practice of scenario planning can be found in, for example: Schwartz P (1991), 'The Art of the Long View', Doubleday/Currency, New York.

7 ASTEC notes that global population growth is rightly considered by many to be a critical long term issue. However, for the purposes of this study the focus was placed on strongly S&T-related drivers for change in Australia over the next 15 years. In this context global population was not considered a key force for change.

8 See for example, Freeman, C (1994), 'Innovation and Growth' in Dodgson, M and Rothwell, R The Handbook of Industrial Innovation, Edward Elgar, Aldershot.

9 ASTEC (1995), 'Australia's Science and Engineering Base for information and communications services and technologies', AGPS, Canberra.

10 House of Representatives Standing Committee on Environment, Recreation and the Arts (1994), 'Working with environment: opportunities for job growth', AGPS, Canberra.

11 Hamel G, and Prahalad CK (1994), 'Competing for the future', Harvard Business School Press, Boston.

12 Sheehan et al. (1995), op cit.

13 ASTEC Commissioned study: Tegart G, (1995), 'Matching Science and Technology to Future Needs: Key Issues for Australia to 2010: The Need to Capture Opportunities from Globalisation' Discussion Paper, July 1995.

14 See for example, Marceau, J (1994) 'Clusters, chains and complexes: three approaches to innovation with a public policy perspective', in Dodgson, M and Rothwell, R The Handbook of Industrial Innovation, Edward Elgar, Aldershot.

15 Federal Race Discrimination Commissioner (1994), 'Water, A report on the provision of Water and Sanitation in remote Aboriginal and Torres Straight Islanders communities', AGPS, Canberra.

16 Bourke, P and Butler, L (1995), op cit.

17 Bourke, P and Butler, L (1995), op cit.

18 Sheehan et al. (1995), op cit

19 'Skills for the Future' (1994), a report prepared by the Association of Professional Engineers, Scientists and Managers of Australia (APESMA).

20 Industry Task Force on Leadership and Management, (1995) 'Enterprising Nation: Renewing Australia's managers to meet the challenges of the Asia-Pacific Century; Karpin Report, AGPS, Canberra.

21 Revealed in a comparative study of the 1992 Japanese Delphi survey and an equivalent German study: National Institute of Science and Technology Policy (NISTEP) and Fraunhofer Institute for Systems and Innovation Research (FhG ISI) (1994), 'Outlook for Japanese and German Future Technology: Comparing Japanese and German Technology Forecast Surveys', NISTEP, Tokyo.

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Appendix A. Membership of Reference Group for Future Needs Study

Dr Don Williams AO (Chair)
Chairperson
Australian Science and Technology Council

Professor Ron Johnston (Deputy Chair)
Deputy Chairperson
Australian Science and Technology Council

Dr Warwick Anderson
Deputy Chairperson
Medical Research Committee
National Health and Medical Research Council

Dr John Bell
Deputy Secretary and Chief Science Adviser
Department of Industry, Science and Tourism

Mr Colin Benjamin
Director
Horizons Network

Professor Paul Bourke
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Academy of the Social Sciences in Australia

Professor Max Brennan AO
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Australian Research Council

Ms Patricia Caswell
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Australian Conservation Foundation

Ms Lyndsey Cattermole
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Aspect Computing Pty Ltd

Dr Edwina Cornish
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Ms Helen Disney
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Ms Barbara Gibson
General Manager, Corporate Advisory Group
ICI Australia Operations Pty Ltd

Professor Graham Johnston
former President
Federation of Australian Scientific and Technological Societies

Mr Bruce Kean AM
Company Director

Dr A R Kjar
President
Australian Industry Research Group

Mr Peter Laver
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Broken Hill Proprietary Ltd

Professor Ian Lowe
Head of School of Science
Faculty of Science and Technology
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Sir Rupert Myers KBE
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Academy of Technological Sciences and Engineering

Sir Gustav Nossal AC CBE
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Professor Mary O'Kane
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University of Adelaide

Sir Arvi Parbo AC
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Mr Charles Perkins AO
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Aboriginal and Torres Strait Islander Commission

Professor Michael Pitman OBE
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Mr John Plunkett
former Chairman
Industry Research and Development Board

Mr John Ralph AO
former President
Business Council of Australia

Mr Peter Robson
former Senior Vice President
Australian Council of Trade Unions

Mr Phillip Ruthven
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Ms Penny Sharpe
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Dr Ric Simes
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Professor Ralph Slatyer AC
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Mr Ian Spicer AM
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Dr John Stocker
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CSIRO

Mrs Deborah Thiele
Chair
Agriculture and Horticulture Training Council of South Australia

Dr John Webster
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The Institution of Engineers, Australia

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