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New Technology:

Implications for Regional and Australian Security

Desmond Ball
and Helen Wilson Editors

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ABSTRACT

New technology is a central feature of the rapidly accelerating pace of change in the present historical epoch. It is a critical element of advanced weapons systems. It is also the key to competitiveness in international markets and to economic growth. As such, it is a fundamental ingredient of national and international security.

This volume describes the new technological developments, with a particular focus on the Asia/Pacific region, and assesses their implications for regional and Australian security.

Part I is concerned with global and regional developments and perspectives. It includes an overview of critical new technologies (such as microelectronics, machine intelligence, new composite materials, biotechnology, etc.), as well as discussions of the Japanese, Malaysian, Indonesian and Indian perspectives on new technologies and their security implications.

Part II focusses on technology and the defence of Australia. It reviews and discusses some of the more significant implications of new technology for Australian security, and highlights some of the important implications for Australian industry. The basic theme is that new technology is not only critical for defence self-reliance, but also that in a regional context of developing industrial and technological capability, an advanced technological base would enable Australia to participate in collaborative regional projects, thus enhancing regional interdependence and security.

Canberra Papers on Strategy and Defence are a series of monograph publications which arise out of the work of the Strategic and Defence Studies Centre, Research School of Pacific Studies, The Australian National University. Previous *Canberra Papers* have covered topics such as the relationship of the superpowers, arms control at both the superpower and South-east Asian regional level, regional strategic relationships and major aspects of Australian defence policy. For a list of those still available refer to the last pages of this volume.

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ACRONYMS AND ABBREVIATIONS

AAAI	Association of Australian Aerospace Industries
ABRI	*Angkatan Bersenjata Republik Indonesia* [Indonesian Armed Forces]
ADF	Australian Defence Force
ADI	Australian Defence Industries Pty Ltd
AFTA	Avionics Fault Tree Analyser (Australia)
AIA	Aerospace Industries Association (U.S.)
AII	Australian Industry Involvement
AIM	Aerospace Industries Malaysia
ANSTO	Australian Nuclear Science and Technology Organisation
ANZAC	Australia and New Zealand Army Corps
AOCI	Australian Ownership and Control of Information
APDC	Asia and Pacific Development Centre
ASC	Australian Submarine Corporation
ASEAN	Association of South East Asian Nations
ASSTASS	Australian Surface Ship Towed Array Surveillance System
ASTA	Aerospace Technologies of Australia Pty Ltd
ASW	Anti-Submarine Warfare
ATC	Air Traffic Control
AWACS	Airborne Warning and Control System
BATAN	*Badan Atom Nasional* [National Nuclear Agency] (Indonesia)
BIR	Admiralty Board of Invention and Research (Britain)
BPIS	*Badan Pengelola Industri Strategis* [Agency for the Management and Development of Strategic Industries] (Indonesia)
BPPT	*Badan Penelitian dan Penerapan Teknologi* [Agency for the Assessment and Application of Technology] (Indonesia)

CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CCD	Charge Coupled Devices
CDS	Chief Defence Scientist (Australia)
CENTO	Turkey, Pakistan, Iran, U.S.
CMACS	Contract Monitoring and Control System (Australia)
CNS	Chief of Naval Staff (Australia)
COCOM	Coordinating Committee for Multilateral Export Controls
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
C^3I	Command, Control, Communications, and Intelligence
DARPA	Defense Advanced Research Projects Agency (U.S.)
DDDRE (R&AT)	Deputy Director, Defense Research and Engineering (Research and Advanced Technology) (U.S.)
DIO	Defence Intelligence Organisation (Australia)
DMC	Defence Manufacturers Council of the Metal Trades Industry Association (Australia)
DNA	Defense Nuclear Agency (U.S.)
DoD	Department of Defense (U.S.)
DoE	Department of Energy (U.S.)
DSB	Defense Science Board (U.S.)
DSTO	Defence Science and Technology Organisation (Australia)
dwt	deadweight ton
EEZ	Exclusive Economic Zone
EIA	Electronic Industries Association (U.S.)
ERL	Electronics Research Laboratory (Australia)
ESCAP	Economic and Social Commission for Asia and the Pacific

FPDA	Five Power Defence Agreement (Singapore, Malaysia, Australia, New Zealand and United Kingdom)
FRG	Federal Republic of Germany
FY	Fiscal Year
GaAs	Gallium Arsenide
GDR	German Democratic Republic
GDP	Gross Domestic Product
GNP	Gross National Product
HF	High Frequency
HFSP	Human Frontier Science Program
Hz	Hertz
IDC	International Data Corporation
IEEE	Institute of Electrical and Electronics Engineers
IMF	International Monetary Fund
IMP	Industrial Master Plan (Malaysia)
IDRDO	Indian Defence Research and Development Organisation
IRS	Indian Remote-Sensing Satellite
IPTN	*Industri Pesawat Terbang Nusantara* [Nusantara Aircraft Factory] (Indonesia)
JORN	Jindalee Operational Radar Network (Australia)
JSP (AS)	Australian Joint Services Publication
LAPAN	*Lembarga Penerbangan Antariksa Nasional* [National Institute for Aeronautics and Space Technology] (Indonesia)

LIPI	*Lembage Ilmu Pengetehuan Indonesia* [Indonesian Institute of Science]
MAD	Mutual Assured Destruction
MAF	Malaysian Armed Forces
MARDI	Malaysian Agriculture Research and Development Institute
MCA	Management and Coordination Agency (Japan)
MCRS	Malaysian Centre for Remote Sensing
MFA	Ministry of Foreign Affairs (Japan)
MIMIC	Microwave and Millimetre Wave Monolithic Integrated Circuits
MIMOS	Malaysian Institute of Microelectronics
MITI	Ministry of International Trade and Industry (Japan)
MoU	Memorandum of Understanding
MRI	Magnetic Resonance Imaging
MRL	Materials Research Laboratory (Australia)
MTIA	Metal Trades Industry Association (Australia)
NAE	National Academy of Engineering (U.S.)
NAS	National Academy of Sciences (U.S.)
NASA	National Aeronautics and Space Administration (U.S.)
NASP	National Aerospace Plane (U.S.)
NATO	North Atlantic Treaty Organisation
NSF	National Science Foundation (Japan)
NSIA	National Security Industrial Association (U.S.)
OECD	Organisation for Economic Cooperation and Development
OSTP	Office of Science and Technology Policy (U.S.)
OTHR	Over-The-Horizon Radar
OUSD(A)	Office of the Under Secretary of Defense for Acquisition (U.S.)

PECC	Pacific Economic Cooperation Conference
PORIM	Palm Oil Research Institute of Malaysia
POW	Prisoner of War
RAAF	Royal Australian Air Force
R&D	Research and Development
RAF	Royal Air Force (Britain)
RAN	Royal Australian Navy
RN	Royal Navy (Britain)
RRI	Rubber Research Institute (Malaysia)
SADS	Sonar Acquisition and Display System (Australia)
SALT	Strategic Arms Limitation Talks
SASC	Senate Armed Services Committee (U.S.)
S&T	Science and Technology
SC	A binaural air tube steerable listening device
SDI	Strategic Defense Initiative
SEANWFZ	Southeast Asia Nuclear Weapons Free Zone
SEI	Software Engineering Institute (U.S.)
SESTASS	Self Streaming Towed Array Sonar System
SHAPE	Supreme Headquarters Allied Powers Europe
SPOT	*Satellite Pour l'Observation de la Terre* (France)
SRT	Science, Research and Technology (Indonesia)
STA	Science and Technology Agency (Japan)
STARS	Software Technology for Adaptable, Reliable Systems (U.S.)
TACAN	Tactical Air Navigation Aid
UKUSA	U.K.-U.S.-Australia (Intelligence Cooperation Agreement)
UNESCO	United Nations Economic, Social and Cultural Organisation

USN	United States Navy
USS	United States Ship
VHF	Very High Frequency
VLSI	Very Large Scale Integration
WRE	Weapons Research Establishment (Australia)
ZOPFAN	Zone of Peace, Freedom and Neutrality

NOTES ON CONTRIBUTORS

DR V.S. ARUNACHALAM, was appointed Scientific Adviser to the Indian Defence Minister in 1982. He acts also as Secretary of the Department of Defence Research and Development. Earlier he had worked in Britain and the United States after gaining his PhD at the University of Wales in 1965. Dr Arunachalam is Chairman of Bharat Dynamics Ltd, Hyderabad (a government-owned company manufacturing anti-tank missiles) and of Mishra Dhatu Nigam Ltd, Hyderabad (a government-owned company manufacturing advanced steels, superalloys and titanium alloys). He is a Fellow and member of numerous learned societies in India. He has written over 75 articles in national and international journals and is currently joint editor of *Alloy Design.*

MAJOR GENERAL J.S. BAKER, AM is Director of the Defence Intelligence Organisation (DIO). He graduated from the Royal Military College Duntroon in 1957 and was commissioned into the Royal Australian Engineers. He then completed a degree in Civil Engineering at Melbourne University. Early regimental experience was gained in a number of Royal Australian Engineer units, including one year in Papua New Guinea, an exchange appointment with the U.S. 25th Infantry Division, and the School of Military Engineering. He attended the Army Staff College in 1967, followed by a number of staff appointments in Army Headquarters. He served in Vietnam in 1970 as a member of the Battle Analysis Team and in 1970-1971 as project officer in 1st Australian Civil Affairs Unit. Promoted Lieutenant Colonel in 1971, he attended the Joint Services Staff College in 1973 and, after further staff appointments, returned to the Joint Services Staff College as a member of the Directing Staff from 1977-1979. Promoted to Colonel in 1979, he was appointed Director of Combat Development - Army, until posted to the Office of the Chief of Defence Force in 1980. In February 1982, he was promoted to Brigadier and assumed the position of Director General Defence Force Development (then Director General Joint Service Policy). This was followed by an appointment as Commander 2nd Military District, and a short term as Deputy Chief of Operations. In November 1987 he was promoted Major General and became Chief of Logistics - Army. On 22 February 1989 he was appointed Director, Joint Intelligence Organisation, now the Defence Intelligence Organisation.

PROFESSOR DESMOND BALL is Head of the Strategic and Defence Studies Centre at the Australian National University, Canberra. He has previously been a Lecturer in International Relations and Military Politics in the Department of Government at the University of Sydney, a Research Fellow in the Center for International Affairs at Harvard University, and a Research Associate at the International Institute for Strategic Studies in London. He is the author of more than 120 academic monographs and articles on nuclear strategy, nuclear weapons, national security decision-making, and Australia's defence policy. His major books include *Politics and Force Levels: The Strategic Missile Program of the Kennedy Administration*, (University of California Press, Berkeley, 1980), *A Suitable Piece of Real Estate: American Installations in Australia*, (Hale & Iremonger, Sydney, 1980), *A Base for Debate: The U.S. Satellite Station at Nurrungar*, (Allen & Unwin, Sydney, London and Boston, 1987), and *Pine Gap: Australia and the U.S. Geostationary Signals Intelligence Satellite Program*, (Allen & Unwin, Sydney, 1988). He is the co-author of *The Ties That Bind: Intelligence Cooperation Between the UKUSA Countries*, (George Allen & Unwin, Sydney, London and Boston, 1985); co-author of *Defend the North: The Case for the Alice Springs-Darwin Railway*, (George Allen & Unwin, Sydney 1985); co-author of *Crisis Stability and Nuclear War*, (American Academy of Arts and Sciences, and Cornell University Peace Studies Program, Ithaca, New York, 1987); editor of *The ANZAC Connection*, (George Allen & Unwin, Sydney, 1985); editor of *Strategy & Defence: Australian Essays*, (George Allen & Unwin, Sydney, 1982); editor of *The Future of Tactical Air Power in the Defence of Australia*, (Australian National University, Canberra, 1976); editor of *Air Power: Global Developments and Australian Perspectives*, (Pergamon-Brassey's Defence Publishers, Sydney, 1988); co-editor of *Problems of Mobilisation in the Defence of Australia*, (Phoenix Defence Publications, Canberra, 1980); co-editor of *Strategic Nuclear Targeting*, (Cornell University Press, Ithaca, New York, 1986); co-editor of *A Vulnerable Country? Civil Resources in the Defence of Australia*, (Australian National University Press, Canberra, 1986); co-editor of *The Future of Arms Control*, (Australian National University Press, Sydney, 1986); co-editor of *Security and Defence: Pacific and Global Perspectives*, (Allen & Unwin, Sydney, 1990); and, co-editor of *Strange Neighbours: The Australia-Indonesia Relationship*, (Allen & Unwin, Sydney, 1991).

THE HON. KIM C. BEAZLEY MP was Minister of State for Defence from 1984 to 1990. He has served in Parliament since 1980, when he won the Perth metropolitan seat of Swan in a general election. In the first Hawke Labor Government he was Minister for Aviation and Minister Assisting the Minister for Defence. Mr Beazley also served as Special Minister of State from 14 July 1983 until 20 January 1984. Mr Beazley holds Masters Degrees from the University of Western Australia and from Oxford, where he studied as a Rhodes Scholar from 1973 until 1976. His Oxford thesis dealt with the strategic significance of the Indian Ocean region. He later co-authored the book *Politics of Intrusion: The Super Powers and the Indian Ocean* (Alternative Publishing, Sydney, 1979). He has been Secretary of the Caucus Foreign Affairs and Defence Committee and a member of the Joint Parliamentary Committee on Foreign Affairs and Defence. Mr Beazley retained the seat of Swan in the July 1987 election, and was sworn in as Minister of State for Defence for a second term on 24 July 1987. In addition to his Ministerial responsibilities he became Vice-President of the Executive Council and leader of the House of Representatives in February 1988. In 1990 he became Minister for Transport and Commnications. Mr Beazley was born in Perth on 14 December 1948.

MR H.A. d'ASSUMPÇAO, Chief Defence Scientist, Department of Defence, obtained the degrees of BE and ME from the University of Adelaide in 1956 and 1968 respectively. He joined the Weapons Research Establishment (WRE) Salisbury as a Scientific Officer in 1956 and worked on long-term attachment to the Royal Radar Establishment (UK) in 1958. In 1959 he returned to WRE. He was appointed Superintending Scientist of the Electronic Warfare Division in the Electronics Research Laboratory (ERL) in 1978, Director of ERL in 1981, and Chief Defence Scientist in 1986. Mr d'Assumpçao began his career in radar electronics, then moved to underwater acoustics and signal processing research in 1961. He is probably best known as the co-inventor of the *Barra* advanced sonobuoy which is used to locate submarines. Mr d'Assumpçao has had extensive involvement with academia and industry and has been an external examiner of higher level degrees. He has played a prominent part in the Technical Cooperation Program which has the aim of fostering collaboration between the defence science communities of Allied nations and is now Australia's representative on the governing body of this Program. Mr d'Assumpçao is the author or co-author of some 66 technical papers.

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DR GEORGE P. MILLBURN was appointed Deputy Director, Defense Research and Engineering (Research and Advanced Technology) [DDDRE(R&AT)] on 4 September 1988. In this position he has responsibility for guidance and oversight of the Science and Technology (S&T) Program of the U.S. Department of Defense (DoD). The S&T Program includes all research, exploratory development and advanced technology demonstration programs conducted by the DoD. Prior to becoming DDDRE(R&AT), Dr Millburn was the Executive Director of the Defense Science Board (DSB), responsible to the Under Secretary of Defense for Acquisition [OUSD(A)] for exercising direction, planning, management, and coordination of the DSB. He has served as Director of the SHAPE Technical Center in The Hague, responsible for the scientific and technical advice and assistance provided to SHAPE. He has also been employed by The Aerospace Corporation; Ford Aeronutronics; and the University of California. Dr Millburn has a PhD in Nuclear Physics from the University of California at Berkeley. Dr Millburn is a member of the Cosmos Club in Washington DC, American Association for the Advancement of Science, American Institute of Astronautics and Aeronautics, Theta Tau, Sigma Xi, and the American Association of Physics Teachers.

MR HIROSHI OTA is Director-General for Scientific and Technological Affairs in the Ministry of Foreign Affairs, Japan. He entered the Ministry in 1960 and served as Director of the Scientific Affairs Division and as Director of the Policy Planning Division before he was assigned to the Embassy of Japan in Washington DC, in 1980. Since his return from the U.S., he served as Deputy Director-General of the Economic Affairs Bureau and of the Economic Cooperation Bureau successively. From January 1987 to June 1989, he was Minister at the Embassy of Japan in Seoul, Korea. He translated Louis Halle's book *Cold War as History* into Japanese (Simul Press, 1968). His articles include 'MAD Strategy and SALT' in *Foreign Ministry Research Monthly*, (No.3), 1979. Mr Ota holds a Bachelor's degree from Tokyo University and a Master's degree in International relations from the Fletcher School of Law and Diplomacy, Medford, Massachusetts.

MRS HELEN WILSON is a research assistant in the Strategic and Defence Studies Centre. She has had wide experience in the fields of industry and transport economics in the Australian Public Service and studied for her BA (Social Sciences) at Deakin University. She is co-editor of *Strange Neighbours: The Australia-Indonesia Relationship*, (Allen & Unwin, Sydney, 1991).

MR ZAINAL ABIDIN HAJI AHMAD is Under-Secretary of the Defence Industry Division in the Malaysian Ministry of Defence, where he coordinates and acts as a catalyst for in-country production and transfer of defence technology. He also serves on the Board of Syarikat Malaysia Explosives. He graduated with a BA, majoring in Geology, from the University of Singapore in 1965. Subsequently, he worked as Assistant Secretary and Assistant Commissioner of Lands and Mines in the State of Negri Sembilan. In 1969 he was awarded a Harvard/Government of Malaysia Diploma in Management Analysis. Mr Zainal joined the Malaysian Diplomatic Service in 1970, serving at the African Institute for Development and Economic Planning in Dakar, Senegal. He also has experience in regional integration and economic community policy studies in the East African Community, European Economic Community and similar organisations in West Africa, the Caribbean and West Asia, relating them to ASEAN. From 1973 until 1975 he served in Washington DC, and, as the alternate member of the *Intelsat* Board of Governors, took a leading role in its activities and was instrumental in obtaining favourable terms for the use of the *Intelsat* Indian Ocean satellite for communication between peninsula Malaysia and Sabah/Sarawak on Borneo Island. During his tour in the Ministry of Foreign Affairs from 1975-1978, he was a member of an inspectorate team examining prospects for better conditions of service, including overseas and representational allowances, and accommodation abroad of the Malaysian Diplomatic Service. In 1978, he was appointed Counsellor and Permanent Representative to ESCAP in Bangkok, and was primarily responsible for representing Malaysia for the Statute of APDC (Asia and Pacific Development Centre) and its final location in Kuala Lumpur. In 1980, he was posted to Medan as Consul-General of Malaysia in Sumatra, Indonesia. In 1982, he was transferred to the Ministry of Education as Under-Secretary, External Affairs Division, involved in UNESCO, SEAMO as well as Bilateral Relations. In 1986 he moved to his present position in the Ministry of Defence.

INTRODUCTION

Desmond Ball

A distinctive characteristic of our age is the rapidly accelerating pace of change. The political and economic changes which General Secretary Mikhail Gorbachev has unleashed within the Soviet Union were unimagineable half a decade ago. The political developments which occurred in Eastern Europe in 1989 could not have been predicted even a year before. While these developments should be earnestly welcomed and supported, it is important to recognise that the consequences will not necessarily be invariably benign. A central Europe of half a dozen independent states, each with serious economic, ethnic and nationality problems, does not auger well for European stability. The years immediately preceding World War II, and perhaps even more those preceding World War I, warrant careful re-examination.

Change in the Asia/Pacific region is no less dynamic. Northeast Asia has become the main source of dynamism in international economic activity. The shift in the world's economic centre of gravity to this region has significant geopolitical and geostrategic implications. The role of the superpowers in the region is declining in relative terms. Bipolarity is now history. Other powers, such as Japan, China, and India, will be increasingly active in the region. Security is becoming more multi-dimensional, with the military dimension decreasing in significance relative to economic and environmental concerns.

We are now witnessing momentous global environmental changes - pollution, desertification, acid rain, ozone depletion and the 'greenhouse' effect - which will affect our future well-being directly as well as provide further cause for international disputation.

Technological development has also become more dynamic and fecund. In the United States, government and industry now spend an estimated US$132 billion a year on technological research and development (about US$40 billion of which is for military R&D). Japan now spends about US$60 a year. New technology has become the key to competitiveness in international markets and to economic growth. As such, it is a fundamental ingredient of national and international security. Economic growth is of course one of the principal causes of environmental degradation. On the other hand, technological innovation provides the only means of sustaining the world's burgeoning population. New technologies also offer possible means of redressing at least some of the environmental trends and hence enhancing environmental security.

In order to provide a forum in which the various and complex new technologies could be described and discussed in readily intelligible fashion, a major international conference was organised by the Strategic and Defence Studies Centre at the Australian National University in Canberra on 29-30 November 1989. The conference was concerned with global, regional and Australia's developments in high technology and the implications of these developments for Australian and regional security. New technology, for the purpose of the conference, was defined quite broadly. It includes civil as well as military aspects. Security was also defined broadly, to include national development and economic well-being in addition to defence politics and capabilities.

This volume consists essentially of the papers which were prepared for that conference, although in all cases they have been substantially revised for publication.

The volume is organised in two parts. Part I is concerned with global and regional developments and perspectives. In Chapter I, Dr George P. Millburn, Deputy Director of Defense Research and Engineering (Research and Advanced Technology) in the U.S. Department of Defense, provides an overview of critical new technologies - including microelectronics, software engineering, parallel computer architectures, machine intelligence, new sensor systems, computational fluid dynamics, hypervelocity projectiles, new composite materials, superconductivity, and biotechnology and processing. Dr Millburn describes the Defense Critical Technologies Plan which has been developed by the U.S. Department of Defense, and which is an attempt by the Department of Defense to address the principal technology issues that face the United States from a defence perspective. He argues that an effective Technologies Plan must be well-balanced - with respect both to civil and military developments and to fundamental and applied research.

In Chapter 2, Mr Hiroshi Ota, the Director-General for Scientific Affairs in the Japanese Ministry of Foreign Affairs, provides a Japanese perspective on new technology. Japan is clearly one of the most advanced technological countries in the world. For most of the post-War period, the Japanese R&D effort has been characterised by a low level of government involvement, an emphasis on applied rather than basic R&D, and a relatively low level of expenditure on defence-related R&D. More recently, Japan has undertaken to strengthen its basic research activities, the government has adopted a more active role (particularly with respect to 'big science' such as space programs, nuclear energy and marine science), greater attention has been accorded defence-related R&D, and international cooperation has been promoted. The security implications of technological development are now also being given more explicit consideration.

Elsewhere in the region, new technology is seen as the key to industrialisation, economic growth and national development more generally.

In Chapter 3, Mr Zainal Abidin Haji Ahmad, Under-Secretary of the Defence Industry Division in the Malaysian Ministry of Defence, discusses the role of technology in the economic development and security processes in Malaysia. He argues that the development of new technology is essential for both economic growth and defence self-reliance, but also that unless the acquisition of technology proceeds within the context of indigenous social and economic circumstances, it can distort the social and economic processes. Hence, Malaysia is being very selective with respect to technological development, focussing on such areas as electronics, aerospace and remote sensing, as well as those designed to capitalise on Malaysia's natural resources (including, most particularly, rubber and marine resources). The approach is cautious and pragmatic.

In Indonesia, as described in Chapter 4 by Ambassador Hasnan Habib, Special Advisor to the Indonesian Minister of State for Research and Technology and Chairman of the Agency for the Assessment and Application of Technology (BPPT), technological development is pursued within the framework of *Tannas*—the concept of *national resilience*, which connotes both security and prosperity. Defence industry and technology is not accorded a high priority in Indonesian development planning. Rather, the emphasis is on 'strategic industries' which contribute to national development: these are primarily oriented to the modernisation of civil infrastructure and production, though they provide an industrial base for defence self-reliance.

In India, as Dr V.S. Arunachalam, Scientific Adviser to the Indian Defence Minister and Secretary of Defence Research and Development, explains in Chapter 5, new technology is viewed as essential to self-reliance and self-determination. It is regarded not just as the key to industrial and economic growth, but also as an essential condition of a viable posture of non-alignment. More generally, the development of new technology, based on indigenous resources and capabilities and reflecting indigenous economic and security concerns, is necessary to enable 'the Indian people to be in control of their own destiny'.

Part II of this volume focuses on technology and the defence of Australia. It reviews and discusses some of the more significant implications of new technology for Australian security, and highlights some of the important implications for Australian industry. In Chapter 6, Mr Kim C. Beazley, the Minister for Defence, discusses 'the special role of technology and research and development in Australian defence planning'. He outlines the strategic concerns that drive the application of technology in defence planning, and discusses at length the impact of new technology on Australia's regional relationships. He concludes that new technology is not only critical for Australian defence self-reliance, but also that in a regional context of developing industrial and technological capability, an advanced technological base would enable Australia to participate in 'technology exchanges and collaboration on defence projects which can positively contribute to regional security'.

In Chapter 7, Major General John Baker, Director of the Defence Intelligence Organisation (DIO), reviews the implications of new technological developments from the perspectives of the Australian strategic planner. He discusses the changing nature of conventional conflict, and stresses the advantages which new surveillance and long-range airpower technologies accord the defence of an island state; he describes Australia's geostrategic environment and the critical importance of capabilities for operations in the sea/air gap; and he assesses the extent to which a strong technological and industrial base can offset Australia's limited population resources. He concludes that 'a self-reliant posture for the defence of Australia against a range of potential threats is achievable within the resources and technological base likely to be available', so long as there is a public commitment 'to sustain the effort'.

Chapters 8 and 9 provide two overviews of significant technological developments in Australia—one from the official standpoint of Defence science and technology, and the other from the viewpoint of the private sector. In Chapter 8, Mr Henry d'Assumpçao, the Chief Defence Scientist, describes the role and capabilities of the Defence Science and Technology Organisation (DSTO)—the second largest R&D organisation in Australia, with a budget of about $200m and a staff of 3,800. The basic functions of DSTO are to provide advice on the level and types of military technology required for the defence of Australia, to design and maintain defence equipment, and to promote a strong industrial and technological infrastructure in Australia. In the end, as he concludes, 'our ability to exploit technology rests on our economic well-being and on our intellectual base and its continual replenishment through the education of our youth'. Economic well-being and sound education policies are thus essential to Australia's long-term security.

In Chapter 9, John Jeremy, Chairman of the Metal Trades Industry Association (MTIA), describes the Australian defence industry; discusses various matters which impact on the way it reacts to advances in technology; and discusses the effects these advances are likely to have on industrial capabilities, processes, and management systems. The problems which are faced by the Australian defence industry, such as its relatively small size and its traditional lack of export orientation, are addressed candidly and positively. The Australian defence industry is changing rapidly, with new technology providing numerous commercial opportunities. There are good prospects for Australia to have a modern and efficient defence industry by the turn of the century.

Chapters 10 and 11 provide two case studies of areas of new technology which have been identified as possible high priority areas for Australia to take a lead in developing in the region. In Chapter 10, Mr P.R. Hart and Mr A.C.O. Gibb discuss the development of and future prospects for underwater technology in Australia. The underwater environment in our region differs markedly from that of the Atlantic—the waters of this region are relatively warm and shallow rather than cold and deep. Australia has pioneered the development of underwater systems designed for this environment, with *Barra* being a pre-eminent example. Our region is essentially maritime, with several important trade routes and sea lines of communication passing through it. Our neighbours share our interest in maritime surveillance and the protection and exploitation of off-shore resources. Messrs Hart and Gibb conclude with a proposal for an underwater industry strategy which would contribute directly to the defence of Australia as well as to a more secure region.

In Chapter 11, Mr Andrew Johnson, Manager of the Systems Engineering Division of Computer Sciences of Australia (CSA), describes the development of software engineering in Australia and assesses the potential for regional cooperation in this field. Australian software engineering is of world class. The industry is growing rapidly; in 1988 it employed 16,000 people and generated revenue of some $846m. Software is critical to the effective and efficient operation of modern defence sensor and weapons systems. It is also a crucial component in the competitiveness of manufacturing and service industries, and hence is crucial to Australia's immediate and future trading performance. Australia is well-positioned to take the lead in software engineering in this region. There are many opportunities, in both the defence and commercial fields, for regional cooperation—such as air traffic control systems, communications networks, and satellite switching systems. Software engineering is a technology perfectly suited to Australia's economic and educational circumstances, to the promotion of defence self-reliance, and to the enhancement of regional collaboration.

Finally, in Chapter 12, Dr Malcolm McIntosh concludes the volume with a discussion of the prospects for Australian defence technology and industry. He notes at the outset that Australia's capabilities for design and development are necessarily quite limited. Our defence and industrial resources are simply very small when measured against a world scale. Nevertheless, there are particular technological areas where Australia does have a comparative advantage, such as those which are based on knowledge of our own natural environment. There is also great scope for collaborative research and development efforts—such as the *Nulka* and *Raven* projects which have been undertaken collaboratively with the U.S. and UK respectively. The restructuring of the Australian economy has made Australian industry more internationally competitive, and hence has provided greater opportunity for collaborative efforts. To date, however, progress has been poor with respect to collaborative regional projects.

Regional cooperation in the development and exploitation of new technology has the potential to greatly enhance regional security. It would contribute not just to economic growth and national development within the region, but also to greater economic interdependence. It is essential for Australia's long-term security that we participate in this regional process. This requires a sound understanding of the technology policies and programs in the region. Insofar as this volume enhances this understanding, it will also contribute to the enhancement of regional security.

ACKNOWLEDGEMENTS

The production of this volume and the organisation of the Conference at the Australian National University on 29-30 November 1989 on which it is based involved the effort of many people to whom we are extremely grateful.

The initial planning and preparation of this project was undertaken by an informal working group which met on several occasions during 1989 and which consisted of myself as Head of the Strategic and Defence Studies Centre; Mr Bob Day, Managing Director of Desiko Pty Ltd and organiser of Australia's International Defence Equipment Exhibition (AIDEX '89), held in Canberra on 28-30 November 1989; Sir William Keys, consultant to AIDEX '89; Mr Ian Meibusch, Executive Director of the Association of Australian Aerospace Industries (AAI), Manager of Defence Projects for the Metal Trades Industry Association (MTIA) and Secretary of the MTIA's Defence Manufacturers' Council; Mr R.C. Wylie, Assistant Secretary of the Industry Policy and Programs Branch, Industry Policy and Operations Division, Department of Defence; and Dr G. Verney, Chief Executive Officer, Industry Policy and Programs Branch, Industry Policy and Operations Division, Department of Defence. The participation of Mr Wylie and Dr Verney in this working group was formally endorsed by the Minister for Defence, the Hon. Kim C. Beazley, and we wish to thank Mr Beazley for this support.

Several companies provided the Strategic and Defence Studies Centre with financial contributions to cover the costs of bringing the overseas participants to the Conference. We are very grateful to Desiko Pty Ltd and to the following members of the MTIA's Defence Manufacturers' Council for their contributions: Australian Defence Industries Pty Ltd, AWA Limited, BHP Aerospace and Electronics Pty Ltd, British Aerospace Australia, Cockatoo Dockyard Pty Ltd, Computer Sciences of Australia Pty Ltd, Evans Deakin Industries Limited, Hawker de Havilland Ltd, James N. Kirby Pty Ltd, Siemens Ltd, and Wormald Defence Systems Pty Ltd. In addition, the Defence Science and Technology Organisation (DSTO) shared with the Centre the costs of the visit to Canberra by Dr V.K. Aatre, Director of the Naval Physical and Oceanographic Laboratory, Cochin, India.

The organisation and administration of the Conference, which was attended by more than 200 people, was the responsibility of Colonel J.O. Langtry and Mrs Helen Wilson, Research Assistant in the Strategic and Defence Studies Centre. They were assisted by Ms Karen Harvey, Ms Pauline Kerr and Miss Carol Staples from the Peace Research Centre at the Australian National University; Mrs Robin Ward, Department of International Relations, Australian National University; and the following members of the Strategic and Defence Studies Centre: Dr Ross Babbage, Mr Denis McLean, Dr Cathy Downes, Commander Graham Johnson, Mrs Elza Sullivan, Mrs Tina Lynam, Ms Leslie McIntyre, Mrs Marlene Arney, Mrs Helen Hookey, Mrs Diane Price, and Mr Steven Bates. I wish to thank them all for their assistance.

Desmond Ball
Strategic and Defence Studies Centre
Australian National University
Canberra
May 1990

PART I

GLOBAL AND REGIONAL TECHNOLOGICAL DEVELOPMENTS AND PERSPECTIVES

CHAPTER 1

NEW TECHNOLOGIES: AN OVERVIEW

George P. Millburn

INTRODUCTION

The *Critical Technologies Plan*[1] (hereafter referred to simply as 'the plan') is a significant attempt by the U.S. Department of Defense (DoD) to address the principal technology issues that face the United States from a defence perspective. It was legislated by Congress in September 1989 (Public Law 100-456), to coincide with its deliberations following the President's budget submission for Fiscal Year (FY) 1990. The plan, to be submitted each year on 15 March, is to address 'the technologies most essential to develop in order to ensure the long-term qualitative superiority of United States weapon systems'.[2]

While the list of critical technologies is the responsibility of the Department of Defense, the DoD would like to take advantage of expertise that is widely distributed. Thus, we seek inputs from industry, academia, other federal agencies, and from our allies and other friendly nations. This chapter is part of that process, a process of learning from one another, understanding one another, and finally, of working together.

LEGISLATION

In 1988 the Senate Armed Services Committee (SASC) asked the Department of Defense to list 20 critical technologies (as defined above), to be selected in consultation with the Department of Energy (DoE). The Department of Defense was asked to give reasons for their

1 U.S. Department of Defense, *The Department of Defense Critical Technologies Plan for the Committee on Armed Services, United States Congress*, (Washington DC, 15 March 1989, Revised 5 May 1989).

2 U.S. Congress, Senate Armed Services Committee, *Department of Defense Authorization for Appropriations for Fiscal Years 1990 and 1991*, (U.S. Government Printing Office, Washington DC, 1989), Part 7, p.6.

selection, to include both product and process technologies, and to provide milestone goals and budget dollars for FY 1990 for each technology. The plan had to compare development of each technology in the U.S. with that in the Soviet Union, to discuss potential contributions from allies, and to make comparison with other industrialised countries with a view to closer cooperation with friendly nations.

Senate Bill S.1352 had not yet been enacted into law as of October 1989. We also wanted to follow through on various initiatives started but not completed in 1988 in the short time available, particularly concerning inputs from industry and from academia. In addition to last year's requirements, the proposed legislation tasks the Secretary of Defense, in consultation with the Secretary of Energy, to provide a list to contain not more than 20 technologies; to establish 20 'lead organisations' for these 20 technologies; to give dollar figures for eleven years, namely the budget year following the plan's submission (FY 1991) and the next five years after that, and the five years preceding it; to provide milestones up to fifteen years into the future; to make recommendations on how to improve cooperative agreements with allies; and to examine the exchange of information with industrialised countries. Other questions raised include the relationship of technology development to the industrial base (both in the U.S. and in other countries), its impact on competitiveness, and the extent of U.S. dependency on foreign development.

The Department of Defense strongly supports this Congressional interest. It throws a considerable burden on the Department, but one that contributes to understanding of technology issues, both national and international. We view this planning process as a continuing development, hopefully getting better each year. How useful it will eventually become will depend to a large extent on how we get started. Therefore, we see the current trail-blazing effort as particularly important.

Other proposed legislation relating to the plan

In 1989 Congress considered a number of proposals, embodied in various bills, coming from various committees, with requests for similar plans or reports. The SASC has asked the Office of Science and Technology Policy (OSTP) to produce a biennial *National Critical Technologies Report* (the first was due on 1 October 1990), and, further, would have the three National Academies - the National Academy of Sciences (NAS), the National Academy of Engineering (NAE), and the Institute of Medicine (IOM) - pursue occasional in-depth studies of technologies selected in the OSTP Report. The legislation also requires DoD to develop an annual Defense industrial base report. The Senate Committee on Commerce, Science and Transportation is interested in having the Department of Commerce provide an *Annual Industrial Technology Report*.[3] The Senate Committee on the Budget has a budgetary perspective: it wants to see both defence and non-defence R&D budgets presented under a single taxonomy, and has proposed that the three Academies study this issue with the object of recommending a single system applicable to all Federal R&D agencies.

STRATEGIC PLANNING IN DOD

The Deputy Director of Defense, Research and Engineering (DDDRE) for Research and Advanced Technology oversees the Science and Technology (S&T) program of the Army, Navy and Air Force. The three Services present their programs to the staff during the S&T Management Reviews held every (northern) summer. In 1988 these reviews were capped with almost a week of discussions in September on the S&T investment strategy. In addition to the three Services, the Defense Advanced Research Projects Agency (DARPA) and the Defense Nuclear Agency (DNA) also participated. In 1989 we repeated a similar investment strategy meeting, again in September. We began a consensus document, a DoD S&T Investment Strategy, which has just been completed. It is the first such document in the DoD, and I expect continual improvements as we learn to do it better every year. The purpose of this strategy is analogous to the *Critical Technologies Plan*, which should eventually become part of the overall strategic planning process.

The strategic planning process in the Department of Defense begins with analysing our missions—we call them mission area analyses. These derive principally from two sources, the national security and the military strategies:

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3 See *Emerging Technologies: A Survey of Technical and Economic Opportunities*, (Technology Administration, Department of Commerce, Washington DC, Spring 1990).

(i) *The Defense Reorganization Act of 1986,* (the Goldwater-Nichols Act, Public Law 99-433) requires the President to submit to Congress an annual report, *The National Security Strategy of the United States.*

(ii) The military strategy is developed by the highest military authority, namely the Joint Chiefs of Staff. These operational strategies are translated into acquisition actions, including R&D, through the documents issued annually by the Secretary of Defense.

The *Defense Guidance,* also required by the *Defense Reorganization Act of 1986,* provides broad guidance to the components of the Department of Defense, and represents the official views of the Secretary of Defense on all DoD activities, including the S&T program. The *S&T Investment Strategy* must thus be consistent with it. More detailed inputs come from reviewing Service programs and working with defence agencies.

The investment strategy document is developed top-down. The strategy starts by setting major long-term goals:

- it describes 14 major thrusts by functional area;
- it indicates capabilities needed for those functions;
- it relates capabilities to systems; describes 17 technology areas; and
- it closes the loop by analysing the impact on systems, capabilities and functions, showing payoffs and resulting military options.

The document concludes with the contribution of the critical technologies toward the major long-term goals with which the investment strategy began.

THE CRITICAL TECHNOLOGIES

As already indicated, the investment strategy is a top-down document and emphasises need- or application-pull, resulting mostly in what are called 'enabling technologies', that is, technologies without which certain capabilities or systems would not be possible. These technologies are ready for application to weapon systems or are already in current use. The critical technologies come partly from 'application pull', and partly from 'technology push'. The latter, sometimes referred to as 'emerging technologies', are the new, highly promising technologies, often associated with relatively large risk, either because of lack of experience and opportunity, or because of uncertainties in their development. Superconductivity and biotechnology are examples.

Selection criteria for the critical technologies include performance, quality, and wide applicability:

- performance: enhancing the performance of conventional weapon systems, and/or providing new military capabilities;
- quality design: improving availability and dependability, and/or improving weapon systems affordability; and
- wide applicability: benefiting a large variety of weapons systems, and/or having spin-off potential for strengthening the industrial base.

The technologies selected (see Table 1) will now be discussed. The first seven or eight of these technologies are very closely related to one another, and, in fact, are part of what could be considered the revolution in our capability in information processing and information handling. These are also technologies that support many applications.

Microelectronic circuitry technology makes possible high-speed computers and more sensitive receivers. The R&D is focused on fabrication or process technology. The emphasis here is on developing better, more reliable methods to produce silicon for microelectronic circuits. Silicon-on-insulator technology will provide integrated circuits that will be less susceptible to interference in military applications and more resistant to damage from either natural or synthetic radiation, which may be present on the battlefield itself.

The second technology is gallium arsenide (GaAs) and other compound semiconductors. The essential distinction between silicon and gallium arsenide is that silicon is a single element, while gallium arsenide is a compound made up of two elements. It requires a much

TABLE 1

CRITICAL TECHNOLOGIES

1	Microelectronic Circuits and Their Fabrication
2	Preparation of GaAs and Other Compound Semiconductors
3	Software Producibility
4	Parallel Computer Architectures
5	Simulation and Modelling
7	Integrated Optics
8	Fibre Optics
9	Sensitive Radars
10	Passive Radars
11	Automatic Target Recognition
12	Phased Arrays
13	Data Fusion
14	Signature Control
15	Computational Fluid Dynamics
16	Air-Breathing Propulsion
17	High Power Microwaves
18	Pulsed Power
19	Hypervelocity Projectiles
20	High-Temperature/High Strength/Low-Weight Composite Materials
21	Superconductivity
22	Biotechnology Materials and Processing

Source: Department of Defense, *The Department of Defense Critical Technologies Plan for the Committee on Armed Services, United States Congress,* (1989), p.11.

more difficult fabrication process. Again, this critical technology is primarily concerned with how we should manufacture gallium arsenide for use in integrated circuits and other types of semiconductor applications. One of the major advantages of gallium arsenide is increased speed. Its application will result in signal and data processing about seven times faster than that achievable with silicon. It also is more resistant to radiation, which will enable us to develop integrated electronic circuits that will survive better in the battlefield environment and in the radiation environment that we typically encounter in space applications.

Gallium arsenide technology is relatively new, whereas silicon has been around for 20 or 30 years. In that time period, something of the order of US$1 billion might have been spent to study the material, so that we understand how to use and apply it in engineering applications. We now must characterise gallium arsenide in much the same way over a period of years before we can expect to achieve the same degree of reliability and producibility of gallium arsenide chips.

The third critical technology - software producibility - is one that has been discussed a great deal in recent years. Our objective here is to reduce the cost of production of reliable, affordable, and secure software. We would like to produce software which is also reusable, so that each time we apply a technology program, there is no need to develop a completely new software program. These objectives are being addressed by the Ada joint program office, the STARS (Software Technology for Adaptable, Reliable Systems) program which applies Ada to defence computers, and the Software Engineering Institute (SEI) at the Carnegie-Mellon University in Pittsburgh, Pennsylvania. Our emphasis on software as a critical technology is further supported by a current effort within the DoD to develop a Software Master Plan. Representatives from various organisations within the Office of the Secretary of Defense, the military departments, and numerous defence agencies are working together to address the software challenges that now confront us. The DoD *Software Master Plan* will define a program by which we can provide increasing capabilities for emerging and existing systems, while at the same time reducing the cost and logistics burden associated with development and life-cycle maintenance of software. The draft plan will be unveiled to the public in February

1990[4], and we will actively solicit industry comments prior to its completion.

Closely allied with software is parallel computer architecture, number four in our list. Parallel computer architectures are essential to greatly increase computational speeds. Present-day computers perform about 10 billion operations per second. This speed may be expected to increase 1,000-fold if the new architecture is successful. There will also be about a 10-fold reduction in the cost of computing. It is very important for applications requiring extraordinarily high-speed computers, such as in computational fluid dynamics, which is another critical technology. Parallel processing is required to fully develop that type of computational power. Other important applications include anti-submarine warfare (ASW) and automatic target recognition, which present great challenges today, but are essential to our visions of future military capabilities.

Machine intelligence and robotics attempt to apply 'artificial intelligence', or the technologies that have been developed over the years under that label, to defence applications. We will be using the concepts of artificial intelligence and expert systems. They must be integrated and implemented through robotics and machines to help us with our battlefield management. At the same time, this technology will be very effective in reducing maintenance and logistics costs, so it meets our criteria both for processes and for affordability.

The next technology, simulation and modeling, is concerned with the person-machine interface problem. We will have to develop technologies for both hardware and analytical simulations. We have, of course, used hardware simulations, particularly in aircraft development, for many years. Simulation of the hardware and of the missions that our pilots have to perform are becoming increasingly realistic. The analytic simulations will greatly reduce the cost of training. In addition, they will provide training capabilities that have not existed up to the present time, for example in war-gaming, or in training commanders from headquarters level down to corps, division,

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4 The plan was released as *The Department of Defense Software Master Plan*, (Defense Acquisition Board, Science and Technology Committee, G.P. Millburn—Chairman, Washington DC, 9 February 1990), Vol.I, Plan of Action; Vol.II, Background.

and even battalion level. A new generation of very low-cost, man-in-the-loop weapons systems simulators, and the means for connecting thousands of them from dozens of sites using a low-cost communications network, has been developed by DARPA. This simulator network, called *Simnet*, can be used to train combat skills and teamwork for troops stationed worldwide, helping offset reductions in field exercises. Further, simulators have been built for weapons systems still on the drawing-board which, when connected to the network, can be used in advance of expensive full-scale engineering development to assess, test, and evaluate the design of these proposed new weapons and their impact on battlefield combat success. This technology has been transferred to the Army, and more recently the Air Force and Navy. Several NATO allies are purchasing this network-compatible technology which allows a more effective means of developing interoperable systems.

Integrated optics, the next critical technology, goes by several names. It is also called optronics, and sometimes photonics. It is, essentially, the marriage of optical and electronic processes and capabilities, both in storage memories and in data processing capabilities. If we are successful in this technology, we will have processing speeds a hundred times faster than today, which is very important on the battlefield for real-time display of information and for rapidly changing information. We also will develop data storage discs about 14 inches or so in diameter, about the size of a long playing record today, which will contain 120 gigabytes of information. This will give individual battlefield commanders ready access to more information than ever before. The commander will be able to bring up immediately, or within a few seconds, detailed maps of areas in which operations may be proposed.

The primary purpose of fibre-optics is the transfer of information, rather than its production or storage. It will be possible to transmit information with ten times current line capacity. Eventually the goal is 10,000 times today's capacity per line—at a tenth of the error rate, which is very important. Information that is erroneous is not effective on the battlefield. At the same time, great benefits will derive from low-loss, high-capacity communication lines without repeaters. There are other important applications of optical fibres, as in submarine detection, and in inertial navigation.

The next set of technologies begins with sensitive radars. Radar is a technology that is relatively mature; it is one of the technologies that was extremely important in World War II, and critical to victory. Thus, sensitive radars are an important extension of a mature technology. Very high-resolution radars, using very wide-bandwidth transmitters, will provide range resolution sufficient to identify targets, and perhaps even targets incorporating low-observable technologies. Such radars could use laser technology or microwave technology.

The development of weapons against radars has been proceeding apace. It is entirely possible that sensors or platforms that emit signals will not survive long in the high-technology battlefield of the future. Passive sensors are very important in order to be able to replace information now supplied by radars, which might have to shut down in battle. A plethora of wavelengths will be used: infrared, visible, ultraviolet, x-ray, microwave, and other portions of the electromagnetic spectrum. Microwave radiometers for use in bad weather, and optical sensors for high resolution, are well developed. Millimetre waves provide better target resolution than microwaves, but the technology is less well developed; hence the MIMIC (Microwave and Millimetre Wave Monolithic Integrated Circuits) program.

The next technology is automatic target recognition. It is a slight departure from our list of more generic technologies, since it integrates several technologies for a specific application. However, it is essential to the future of our weapons systems—very smart weapons, such as terminal submunitions that can be self-guided to targets, and so overcome the numerical advantage of the enemy by dispensing weapons with a probability of kill approaching unity. These can be distributed by delivery systems in clusters, so that one delivery system can kill many targets. This cannot be done without the ability to identify separate targets, including eventually targets that the enemy has made every effort to hide. We do not have that capability today. It is questionable whether we will ever be able to develop such a capability with today's technology, or whether we must develop some yet undiscovered technology for that purpose. This technology will assist operators in tanks and aircraft to identify targets and to better target their weapons.

Phased arrays constitute a very important technology, one that can be applied wherever there are radiators. Not only radars, but acoustic phased arrays and optical phased arrays will be very important in the future. It will be possible, using this technology, for example, to develop what some people call 'smart skins'. For example, consider the current AWACS aircraft, which has a large radar antenna sitting above the fuselage. It may be possible in the future to develop a covering for the fuselage of the aircraft to replace that antenna. This has the advantage of greatly reducing the drag on the aircraft, and also of making it much more difficult to identify its mission. In some respects, smart skins will be essential if we wish to have antennas on aircraft that will not interfere with its stealth characteristics. Phased arrays are also very important because they make it possible to steer the radar beam very quickly. For example, if someone is attempting to jam a particular radar, it is possible to steer the antenna pattern in such a way as to greatly reduce the amount of energy that the jammer will put into the receiver.

We are developing sensors to collect data at a far greater rate than we can today, along with capabilities to transmit that information at a much greater rate. What we have to do now is tie these capabilities into the next critical technology, data fusion technology. We have to be able to take information and data which will be coming in from many different sensors and in many different forms, and combine it all together and display it so that the end-user can interpret it quickly, screen out all the data that is extraneous to the mission being performed, and use it very quickly, essentially in real-time. This battlefield management technology will have application to smart weapons, to terminal self-guided cluster weapons, and to space surveillance and other surveillance systems which maintain surveillance over very large areas.

Signature control, which includes stealth, is a very critical technology. It is also one that is closely guarded. Most of the information is compartmentalised. What we are doing, however, is looking at this technology from the point of view of the physics and its basic applications, particularly with respect to the eventual application of trying to defeat enemy stealth capabilities. Historically, it has been true that the Soviets, five to ten years after we have fielded a given technology, will field their own version. We have to prepare our defence systems, for example, to handle stealthy targets. This technology is trying not only to increase the application of camouflage, concealment, and deception, but also to counter it.

Computational fluid dynamics is a very exciting technology. It is under development jointly by the Department of Defense and the National Aeronautics and Space Agency (NASA). Our first applications of it very likely will be in trying to model the hypersonic flow above Mach 8. The National Aerospace Plane (NASP) will fly at orbital speeds of Mach 20. This technology will have the capability of solving the fluid flow equations, the equations that govern the flow of air over objects, in three dimensions. We currently have the capability of doing this in two dimensions, but it is essential that we have it in three dimensions. It is also essential for the development of the NASP because we will be marrying the engine with the airframe. We must be able to solve the problem of the chemistry of the airflow through the engine and over the surface of the aircraft. Real gas equations and ionisation phenomena will have to be considered. It also will be very important in the future for significant drag reductions in ships and submarines, and for quieting the submarine wakes and the wakes behind ships.

The next critical technology is air-breathing propulsion. If we are successful, we will be able to deliver engines that will have two times the thrust-to-weight ratio of our current engines such that it will conserve 50 per cent of the fuel. This will result in much longer range for our aircraft. The improved thrust-to-weight ratio will mean that, in the future, we will have aircraft with the current capabilities of the F-15, for example, but with vertical/short-takeoff-and-landing capabilities. The technology is responsive to the changing threat that we perceive and the need for us to operate in areas of the world where we lack air bases or landing fields capable of handling current aircraft with the capability of the F-15. The commercial applications are also evident. Air breathing propulsion is a mature technology, but we will be able to make a significant improvement in it. The capabilities of our jet engines have increased over the years because of steady, slow improvements in the technology, not because of revolutionary developments. We are aiming at steady evolutionary progress with this thrust and this critical technology.

High power microwaves is the next critical technology. We are developing it jointly with the DoE. The capability resides primarily in the National Laboratories at Livermore, Los Alamos, and Sandia. They are working very closely with us. Our primary concern here is the survivability of many of our very highly capable electronic systems. High-power microwaves produce radiation, which, in some respects, is similar to that produced by radiation from nuclear weapons at high altitudes. We are interested in seeing how this radiation might affect the survivability of some of our weapons systems and some of our data systems in the field. We also want to examine whether we can apply this technology to damage enemy systems.

Pulsed power is a technology which is specifically aimed at directed energy weapons and anti-armour weapons. It is also important for high-powered microwave weapons and electromagnetic guns. One of the main thrusts here is to improve the energy density storage capability of capacitors by an order of magnitude or more.

The next technology, hypervelocity projectiles, is again more of an application technology than a basic technology. This is in response to the difficulty of defeating advanced armour on the battlefield. It is also very important for electromagnetic guns.

The next technology is essentially a process technology. To apply polymatrix composites, metal matrix composites, ceramic matrix composites, and other types of advanced materials we must learn to manufacture them reproduceably, reliably, and at a cost we can afford. In order to develop the NASP, we will need new materials—materials that will not only survive the thermal environment, but also provide the necessary strength. Materials technology also offers an alternative to our increasing dependence on foreign supplies. We can in some cases supplant titanium and other types of metals, for which we do not have domestic or reliable foreign sources, with materials that we have developed in their place.

The next two technologies, superconductivity and biotechnology, are just emerging from the basic sciences, but have not yet been applied in a meaningful way to military applications beyond medical ones (biotechnology). Exactly how we will apply them is still to be determined.

In superconductivity, the emphasis is currently on high-temperature superconductivity. However, it is important not to ignore low-temperature superconductivity. In our high-temperature work, we must first focus on understanding the physics of high-temperature superconductivity and develop materials to extend the regime in which we can apply it. Examples of future applications are electric-drive systems for ships, generators, energy storage (energy storage is currently under development by the Strategic Defense Initiative Organization), and very high speed computers.

Most of the applications of biotechnology are in medicine, and we have largely omitted them from our list, although it is important to develop vaccines to protect troops, particularly for areas of the world where our citizens are not immune to the diseases. We particularly need sensors to warn if any of our troops are under attack by chemical or biological weapons and the nature of those weapons. Responses to attacks by chemical or biological agents are quite different, depending on the types. We may not know specifically what the agents are before they are actually used. The inverse is also true. This technology can be used by other countries or individuals to develop completely new chemical and biological agents very quickly. We must be prepared to counter such a future threat at short notice. We would like to expand the use of biotechnology to genetic engineering, applying engineering principles similar to ones applied today to atomic or nuclear physics. One of the first applications might be in waste disposal. Already, there are people developing biological agents that will dissolve toxic waste; when they have finally converted all of the toxic materials, the agents run out of their food source and die without leaving any environmental hazard behind them. If successful, we shall have greatly decreased the costs of some of our waste disposal clean-up efforts. The Department of Defense has a major problem in that area, and one where we certainly would like to see the costs reduced by a factor of ten or a hundred.

Visionaries among us predict the application of genetic engineering to products like biosensors, bioprocessors, and memories. We carry in our heads the best biocomputer that has ever been invented. If we can apply the technology to develop only one-tenth the capabilities of our brain, we will have computers that are vastly more capable than those existing today, and memory banks which would put to shame anything that we currently envisage.

THE NEED FOR A BALANCED SCIENCE AND TECHNOLOGY PROGRAM

The plan is concerned with the 'technologies most essential to develop in order to ensure the long-term qualitative superiority of U.S. weapon systems'. However, no weapon in the hands of service operator who are poorly trained will achieve its superior potential. In order to keep the list focussed, technologies that are critical but do not impinge directly on the intrinsic performance of military systems were omitted from the list. Examples are training, environmental R&D, and medical research. There was no vaccine to stem the 1918 flu epidemic, which felled more U.S. soldiers than died from combat in World War I—thanks to medical research since that time, such a setback would be preventable today.

Thus, a technology absent from the list must not automatically be regarded as 'not important'. For example, the oceans are critical to the Navy and to the nation; the selection of acoustic array sites based on a knowledge of the ocean floor vastly affects the ability to find enemy submarines lurking in the deep. These technologies could also have been listed as 'critical'. So could technologies to help protect against battlefield hazards such as chemical and biological weapons, or high-energy lasers. They were not listed in order to keep the list focussed.

This brings up the point of balance. An effective S&T program must be well-balanced. There is no magic bullet. The critical technologies will have the greatest impact on performance, quality, and wide applicability, but only if supported by a balanced program advancing all technologies. Moreover, allowance must be made for human fallibility and bias; a degree of subjectivity will enter any listing. All technologies are important.

Having said all this, there still is a need for taking stock, for planning, for investing strategically, for developing a critical technologies plan, but understanding its limitations.

INTERNATIONAL COMPARISONS

We were asked to compare what other countries are doing. Table 2, taken from the first *Critical Technologies Plan*, summarises the status of technologies in the major country groups of interest, the Warsaw Pact countries, our NATO allies, and Japan.

TABLE 2
SUMMARY OF FOREIGN TECHNOLOGICAL CAPABILITIES

CRITICAL TECHNOLOGIES	WARSAW PACT	NATO ALLIES	JAPAN
1 Microelectronic Circuits & their Fabrication	■	□□	□□□□
2 Preparation of GaAs & other Compound Semiconductors	■	□□	□□□□
3 Software Producibility	■	□□	□□
4 Parallel Computer Architectures	■	□□	□□
5 Machine Intelligence/Robotics	■	□□□	□□□□
6 Simulation & Modelling	■	□□	□□
7 Integrated Optics	■■	□□□	□□□□
8 Fiber Optics	■	□□	□□□
9 Sensitive Radars	■	□□	□□
10 Passive Sensors	■■	□□	□□
11 Automatic Target Recognition	■■	□□	□□
12 Phased Arrays	■	□□	□
13 Data Fusion	■■	□□	□□
14 Signature Control	■	□□	NA
15 Computational Fluid Dynamics	■	□□	□□
16 Air-Breathing Propulsion	■■	□□□	□□
17 High Power Microwaves	■■■■	□□	
18 Pulsed Power	■■■■	□□	□□
19 Hypervelocity Projectiles	■■■	□□	□□
20 High-Temperature/High-Strength/Low-Weight Composite Materials	■■	□□□	□□□
21 Superconductivity	■■	□□	□□□□
22 Biotechnology Materials & Processing	■■	□□□	□□□□

Position of Warsaw Pact relative to the United States		Capabilities of allies to contribute to the technology	
■■■■	Significant leads in some niches of technology	□□□□	Significantly ahead in some niches of technology
■■■	Generally on a par with the United States	□□□	Capable of making major contributions
■■	Generally lagging except in some areas	□□	Capable of making some contributions
■	Lagging in all important aspects	□	Unlikely to make any immediate contribution

Source: *The Department of Defense Critical Technologies Plan,* (1989), p.11.

An important point is the method we used to show the standings of these countries relative to the U.S.. We asked ourselves what is the most meaningful way to present our findings to Congress, seeing that one of the principal motivations is to obtain benefit through cooperation where benefit is to be obtained. Therefore, any broad comparison was ruled out, since cooperation must be based on specific, well-defined projects. So, we subdivided each critical technology into niches of technology and compared them separately. The 'grading' shown (from a low of one square to a high of four squares) reflects the highest 'mark' in any one niche technology in that critical technology, and thus becomes a measure of how worthwhile it might be to undertake a cooperative project. The Table should not be misunderstood: four squares do not mean that the country in question is necessarily ahead overall in that technology.

DEFENCE AND CIVILIAN SCIENCE AND TECHNOLOGY (S&T)

There is strong overlap among technologies for military and commercial applications. In developing our plan, we would like to take advantage of expertise to be found in many places: in industry, academia, and other government agencies, not only in defence. We would like to tap into this expertise to make our plan the best one possible.

Three industry associations, the National Security Industrial Association (NSIA), the Aerospace Industries Association (AIA), and the Electronic Industries Association (EIA), are working together to undertake an industry survey[5] based on our first *Critical Technologies Plan*. Among them they cover the industrial sectors most concerned with DoD's critical technologies. Questionnaires are being mailed out, and responses will be tabulated to such questions as the interests and activities in the technologies listed. Our goal is to estimate the interest of industry in these technologies, the magnitude of the industrial effort, and also to receive good counsel from industry experts. We also want to find out about programs and plans in universities regarding these technologies, and to avail ourselves of their expertise in planning our S&T strategy.

Other government agencies having strong activities or interests in science and technology, such as the OSTP, NASA, National

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5 The results received by mid-1990 indicated substantial agreement on the technologies selected.

Science Foundation (NSF), and of course the DoE, will be consulted. We worked closely with DoE on the first plan. In 1989 we seek even closer coordination with DoE and their National Laboratories; eventually we would like to work more closely with other technology oriented agencies of the Federal Government in sharing plans for technology development.

We are also required by such legislation to inform ourselves of progress in S&T among our allies and to work more closely with them, which is one reason why I am pleased to be contributing this chapter.

SUMMING UP

Let me reiterate that we must take all technologies into account in our strategic planning process. While the critical technologies will provide the greatest leverage in enhanced performance and quality, we must steadily develop all technologies. We should not expect miracles, but look mainly for steady yearly improvements, which will compound into major steps forward. Vision, steadfastness, and stable funding of our research programs is essential. There is nothing more detrimental, more harmful, to progress in research than constant uncertainty in funding.

CHAPTER 2
NEW TECHNOLOGY: THE JAPANESE PERSPECTIVE

Hiroshi Ota

The world today is characterised by a new dynamic stage in technological development. Pessimistic views prevailed in the 1970s concerning technological innovations, reflecting the stagnation in the world economy following the first oil crisis. As the 1980s are coming to the end, however, we are witnessing the advent of new innovative high technologies, including microelectronics, new materials and biotechnologies, as well as various new technologies with broader applications emerging.[1]

In such a world environment, Japanese technologies are equal to the world's best.

It is difficult to compare the stages of development of technological innovation among different countries, according to the surveys conducted by the Japanese Ministry of International Trade and Industry and the Science and Technology Agency. However, among private firms and national laboratories working in the three categories of conventional, advanced, and the most advanced technologies, Japanese development is near the forefront.[2]

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1 Ministry of International Trade and Industry (MITI) (ed.), *Nijuisseiki Sangyo Shakai no Kihon Koso* [Basic Plans for the Industrial Society in the 21st Century], (Tokyo, 1986), p.46.

2 Ministry on International Trade and Industry (ed.), *Sangyo Gijutsu no Doko to Kadai* [Trends and Tasks in Industrial Technology], (Tokyo, 1988), pp.27-49.

Conventional Technologies

Japan is at the most advanced level in most of the conventional technologies in products such as basic materials including steel, household electronic goods and office equipment.

High Technologies

Among the 40 high technology products surveyed, Japan ranks first in such items as high-strength steel, fine ceramics, semiconductor laser, CCD (charge coupled devices), semiconductor memory devices, spectrum analysers and photovoltaic power generation.

Japan is regarded as on a par with the U.S. in such items as amorphous alloys, superconductive materials, magneto-optical disks, assembly robotics, laser processing machines and communication satellites.

On the whole, Japanese technologies are considered to be amongst the world's best in 90 per cent of all the high technology products. On the other hand, Japan lags behind the highest international standards in such areas as aircraft engines, MRI (magnetic resonance imaging), data bases and satellite-launching rockets. These are areas where systematic integration technologies are required, or where Japan has had relatively little experience.

Most Advanced Basic Technologies

In the majority of the 47 areas of the most advanced basic technologies surveyed, which are expected to open new prospects for development towards the 21st century, Japan ranks lower than those of its major international competitors. Wide gaps exist between Japan and the U.S. in such areas as life sciences and the marine and earth sciences. Japan is also behind the U.S. in some fields belonging to the matter and material sciences and in the information and electronics sciences. *Vis-à-vis* European countries, Japan is on the whole more advanced in the information and electronics sciences, equal in matter and material sciences, and lags behind in life sciences and the marine and earth sciences. Japan is recognised as the world leader or close to that position in such fields as ferromagnetic materials, advanced functional carbon composite materials, advanced functional glass and amorphous materials in new material sciences, quantum functional devices in electronics sciences, and bio-chemical effect utilisation technology. The latter relates to both new materials sciences and bio-technologies sciences.[3]

It is interesting to note how the U.S. evaluates the level of Japanese technology. According to the *Critical Technologies Plan* released by the U.S. Department of Defense in March 1989, Japan is viewed as leading the world among the 22 critical technologies selected, in the following three technologies: gallium arsenide (GaAs) and other compound semiconductors, fibre optics, and biotechnology materials and processing. It also pointed out that Japan leads the U.S. in some aspects of the following technologies: microelectronic circuits and their fabrication, machine intelligence/robotics, and high-temperature/ high-strength/ light-weight composite materials.[4]

The *Critical Technologies Plan* evaluates the development of Japanese technologies more highly than does our own assessment. In fibre optics, for example, Japan recognises its parity with the U.S., while the *Plan* states Japan is ahead. In the field of machine intelligence/robotics, the Japanese evaluate the U.S. as its equal in some areas and ahead of Japan in others, while the *Plan* regards Japan as being slighty more advanced.

CHARACTERISTICS OF JAPANESE RESEARCH AND DEVELOPMENT ACTIVITIES

Leading Role of the Private Sector

The research and development activities in Japan expanded with its economic development following World War II. This expansion is due mainly to the efforts of the private sector. Since the first oil crisis, R&D activities in Japan have recorded the highest rate of growth among the industrialised countries. At the same time, the structural base of knowledge intensification industries has been transformed with the private sector acting as catalyst.

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3 Science and Technology Agency (STA), *Kagaku Gijutsu Hakusho* [White Paper on Science and Technology], (Tokyo, 1988), pp.18-22.

4 Department of Defense, *The Department of Defense Critical Technologies Plan*, (Washington DC, 1989).

The share of the private sector in total R&D expenditure in Japan was 70.3 per cent in 1977 and 78.4 per cent in 1987. In recent years some 80 per cent of such expenditure has been financed by the private sector.[5] This is by far the highest rate among the major industrialised nations. For example, in 1986 the rate was 79 per cent for Japan, 63 per cent for West Germany, 61 per cent for the United Kingdom, 52 per cent for the U.S. and 47 per cent for France.[6]

The ratio of Japan's privately financed R&D expenditure to its GNP increased from 0.99 per cent in 1965 to 2.19 per cent in 1985. This rate has remained the highest among the major industrialised countries and recorded a marked increase after the second oil crisis. The equivalent ratios for other major industrialised nations in 1985 were 1.71 per cent for West Germany; 1.45 per cent for U.S.; and 1.08 per cent for France.

One of the factors contributing to this strong R&D activity in the private sector is the high level of competition among private companies. Also, as the industry responded with increased levels of R&D activity, Japanese private firms used the 'dollar shock' and two oil crises to provide further opportunities to expand their investments in R&D activities.

The second oil crisis, in particular, stimulated R&D activity in Japan. The annual growth rate of the ratio of privately financed R&D expenditure to GNP jumped from the annual average of 2.4 per cent in 1975-80 to an annual average of 7.3 per cent in 1980-85.[7]

Low Level of Government R&D Expenditure

These strong private efforts contrast with the relatively small amount the Japanese government spends on research and development. In absolute terms, the Japanese government budget for

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5 Management and Coordination Agency (MCA)—Statistics Bureau, *Kagaku Gijutsu Kenkyu Chosa Hokoku* [Report on the Survey of Research and Development], (Tokyo, 1988), p.29.

6 National Science Foundation (NSF), *International Science and Technology Data Update: 1988* (NSF 89-307), (Washington DC, 1988), p.12.

7 MITI, *Sangyo Gijutsu no Doko to Kadai*, pp. 54-59.

R&D was ¥1,814.8 billion (US$13.6 billion) for FY 1989[8] while it was US$62.7 billion for FY 1989 in the U.S.[9] and DM 21.4 billion (US$11.9 billion) for FY 1987 in West Germany[10].

The ratio of Japanese Government R&D expenditure to its overall expenditure continues to be the lowest among the major industrialised nations. In 1985 it was 2.9 per cent while the corresponding figures were 7.1 per cent for France, 5.1 per cent for the U.S., 5 per cent for West Germany and 3.4 per cent for the United Kingdom. Japan compares even more poorly in terms of recent achievements. During the five years from 1981 the ratio for Japan increased only by 0.1 per cent while other countries recorded significant increases: 17 per cent for France, 13.3 per cent for West Germany, 10.4 per cent for the U.S. and 3.8 per cent for the United Kingdom.

As a result, the ratio of Japanese government R&D expenditure to its GNP has always remained around the half of the other industrialised nations. The ratio in 1985 was 0.58 per cent for Japan, 1.27 per cent for the U.S., 1.25 per cent for France, 1.12 per cent for West Germany and 0.99 per cent for the United Kingdom.

The following factors can be cited as contributing to the relatively low level of government R&D expenditure in Japan:

(i) Until recently, most of the priority research areas in Japan were those in the application or development stage

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8 Science and Technology Agency (STA), *Heisei Gannendo Kagaku Gijutsu Kankei Yosan* [Budget related to Science and Technology for Fiscal Year 1989], (Tokyo, 1989), p.4. Currency conversion from the Japanese yen to the U.S. dollar was calculated at the average exchange rate for the first half of 1989 of 133.3 yen to a dollar.

9 National Science Foundation, *National Patterns of R&D Resources 1989 Final Report*, (NSF 89-308), (Washington DC, 1989), p.2.

10 Federal Republic of Germany, Federal Ministry for Research and Technology, *Report of the Federal Government on Research 1988*, (Bonn, 1988), p.54. Currency conversion from the German mark to the U.S. dollar was calculated at the average exchange rate for 1987 of 1.797 marks to a dollar.

which were considered to be areas to be covered primarily by private industry.

(ii) The government tended to promote R&D activities conducted by the private sector.

(iii) In a period of stringent budgetary restraints science and technology areas were not considered priority areas.[11]

(iv) Japan spends relatively little in defence-related research and development. The science and technology budget allocated to the Self-Defense Agency in 1989 was ¥93 billion (US$698m)—only 5.1 per cent of the total.[12] When compared internationally, the share of the defence-related segment in the national science and technology budget in 1987 was 68.6 per cent in the U.S., 50.3 per cent in the United Kingdom, 34.1 per cent in France, 12.5 per cent in West Germany, and, 4.5 per cent in Japan.[13]

Japan thus compares more favorably with other industrialised countries in terms of the non-defence related S&T budget than in the case of the total S&T budget. The government civil (non-defence) R&D appropriations as a percentage of GDP in 1987 were 0.96 per cent for West Germany, 0.91 per cent for France, 0.6 per cent for Japan, 0.58 per cent for the United Kingdom and 0.4 per cent for the U.S., respectively.[14]

Low Level of Research Expenditure in Basic Science

The third characteristic of R&D activity in Japan is the emphasis on developmental research. In the total R&D expenditure for FY 1989, expenditure on development research accounted for 61.7

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11 MITI, *Sangyo Gijutsu no Doko to Kadai*, pp.59-60.

12 STA, *Heisei Gannendo Kagaku Gijutsu Kankei Yosan*, pp.6-8. Currency conversion from the Japanese yen to the U.S. dollar was calculated at the annual average exchange rate for the first half of 1989 of 133.3 yen to a dollar.

13 NSF, *International Science and Technology Data Update: 1988*, p.10.

14 Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators 1989/1*, (Paris, 1989), p.30.

per cent, application research for 24.3 per cent and basic research only for 14 per cent.[15]

Japan's expenditure, to date, on basic research has been limited. If one compares the ratio of Japanese expenditure for basic research to its GNP with the corresponding figures of other industrialised nations in accordance with the OECD method, the ratio was 11.1 per cent for Japan in 1986, 12.2 per cent for the U.S. in 1986 (if defence-related research expenditure is excluded the figure is 17.6 per cent), 20.5 per cent for West Germany in 1983, and 20.9 per cent for France in 1979.[16]

The proportion of total expenditure for development research, application research and basic research varies with the sectors of performance: 71.7 per cent, 21.7 per cent and 6.6 per cent for private firms; 58.2 per cent, 26 per cent and 15.8 per cent for research institutions; and 8.4 per cent, 37.4 per cent and 54.2 per cent for universities, respectively, in FY 1987. In summary, private firms and research institutions have concentrated their research in the development area, while universities have been focussing on the area of basic research.[17]

The number of Nobel prizes awarded to Japanese scientists is symbolic of the unimpressiveness of Japanese activities in the international arena of basic research. The number of Nobel prize winners in natural sciences (that is, excluding literature, peace and economics) in major industrialised nations since 1901 are 152 for the U.S., 65 for the United Kingdom, 57 for Germany (including both GDR and FRG), 23 for France and 5 for Japan.[18]

Another indicator of basic research undertaken in a given country is the number of scientific theses quoted in other countries. The number in 1982 was 7,099 for the U.S., 2,674 for West Germany, 2,500 for France, 2, 453 for the United Kingdom and 1,059 for Japan.[19]

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15 MCA, *Kagaku Gijutsu Kenkyu Chosa Hokoku*, p.29.

16 MITI, *Sangyo Gijutsu no Doko to Kadai*, p.70.

17 MCA, *Kagaku Gijutsu Kenkyu Chosa Hokoku*, p.30.

18 Science and Technology Agency, *Kagaku Gijutsu Yoran* [Indicators of Science and Technology 1989], (Tokyo, 1989), pp.34-35.

19 Seisaku Kagaku Kenkyujo [Policy Science Research Unit], *Gijutsu Kaihatsu Sokushin no Joken Chosa Hokokusho* [Report on

PROSPECTS OF NEW TECHNOLOGIES AND TASKS FOR JAPAN

Main Features of New Technologies

As mentioned at the outset, the world is now witnessing the advent of a new era in technological innovation. It is no exaggeration to say that a new development stage, which may be referred to as the Third Technological Innovation, is underway centering around the fields of microelectronics, new materials and biotechnologies. The First Technological Innovation took place from the 17th to the 18th centuries with the development of the technologies of the internal steam engine and iron manufacturing, and the Second Technological Innovation covered the period from the end of the 19th century into the 20th century with the invention of electric power generation, telecommunications, automobiles, internal combustion and oil related technologies.[20]

Several characteristics can be pointed out concerning the emerging technologies which feature in the Third Technological Innovation. In the first place, these technologies are both high-level and multi-functional, and based upon refining and integration of the processing and manufacturing technologies. They will lead to significant development in the application areas and an intensification of spin-off effects.

In the field of electronics, for example, the development of high-performance integrated circuitry, which would by far surpass the present level of integration, reliance and speed, such as the 100 megabit integrated circuit, compound semiconductor, Josephson device and optical integrated circuit, is expected to promote wide application in areas such as computers, machine tools, aviation and high-performance robotics. In the field of computers, further progress is expected in the development of parallel general-purpose computers, neurocomputers and optical computers.

In the field of new materials, superconductive materials with high transition temperature, high magnetic field and high current density will be developed. These materials will be required to meet

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Investigation of Conditions concerning the Promotion of Technological Development], (Tokyo, 1986), p.43.

20 Masataka Kosaka (ed.), *Japan's Choices*, (Printer Publishers, London, 1989), pp.22-25.

the enormous increase in wire rod capacity, and efficiency in electric power generation and transmission, in such areas as linear motor cars, medical appliances, superconducting electric power generation and transmission, and heavy electric machinery. The production of bio-ceramics, with high adaptability to human orgainisms and high durability within the living body, could dramatically improve medical technologies through their use in artificial teeth roots, artificial bones, artificial joints and so on. The development of ceramics could also result in the development of light-weight, high-performance ceramic engines.

Biotechnology is one of the most promising new technologies. Researchers may succeed in utilising and applying the functions of living organs by the creation of cell culture by gene manipulation, material conversion by bio-reactors, bio-system technologies which integrate extraction and separation processes, and protein engineering which enables artificial designing and creation of proteins that manage the very function of the living body. If so, enormous improvement in the efficiency of production processes and in the quality of products would become possible not just in chemical, food, textile and medical industries but also in the electronics industry.[21]

The second characteristic of these emerging technologies is the fusion of different technologies from different fields. The technological fusion which used to take place within the chemical, mechanical, metallic and electric systems is now changing. In the 1980s, fusion between different technological systems such as between the mechanical and the electronic systems or between the electronic and the chemical systems became possible. In the case of the mechanical and microelectronics technologies, for example, the development of the integrated circuit gave rise to the development of fusion between these two technologies, which came to be called 'mechatronics', for example, the computerised-numerically- controlled machine tools and high-performance robotics. In the future there is great potential for the development of a so-called new chemical area consisting of technologies based upon the fusion of microelectronic and chemical technologies, for example, composite semiconductors and optical integrated circuits. It is also likely that the fusion relations centering around biotechnologies would develop in food, chemical

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21 MITI, *Nijuisseiki Sangyo Shakai no Kihon Koso*, pp.46-47.

and medical industries. In new materials such as new ceramics, new metallic materials, high-performance high-polymer materials and composite materials, the fusion between the manufacturing technologies and the technologies for their utilisation would further enlarge the possible application areas of new materials.[22]

The third characteristic of these emerging technologies is significant progress in large-scale-system integration technologies, including nuclear energy, space, aviation and marine sciences.

Technologies are being developed in the field of nuclear energy—in fast-breeder reactors and high-level radioactive waste management concurrently with technologies to further develop conventional nuclear reactors, reprocessing technologies and enrichment processes. Moreover, research activities continue on nuclear fusion—the ultimate source of energy.

Satellites are being developed and utilised in the expanding area of space development for scientific observation, communication, broadcast, weather observation, natural resources exploration and environment protection. In space research, the Space Station program is being promoted through international collaboration among the U.S., several European countries, Japan and Canada to conduct research in areas such as new materials; and, to utilise the unique environment of outer space with its micro-gravity and high vacuum.

Marine sciences offer many possibilities. Various developments are expected in a host of areas such as the development of resources cultivation technologies which would promote the utilisation of living resources in the marine environment through the exploitation of its inherent productivity and of the useful mineral resources beneath the seabed including oil, natural gas, and manganese and cobalt rich crust nodules. The utilisation of reproducible energy sources including waves, ocean thermal energy and currents, and the wider use of the marine environment as a place for habitation, industrial production and storage are also possibilities.

The Prospect for New Technologies in Japan

The phenomena which can be referred to as the Third Technological Innovation are also observed in Japan. It has been said

22 *Ibid.*, pp.49-51.

that Japanese society has shown a strong tendency to accept and adapt itself to new technologies with relative ease. In addition, it is often pointed out that Japan is rich in technological tradition which supports the ready introduction of high technologies. For example, ceramics technology, one of the indispensable components for the development of electronics and one where Japan leads the world, has blossomed with the heritage of two thousand years' tradition in earthenware and china.[23]

It is expected in the years prior to the 21st century that Japanese technology will continue its dynamic growth and research and development will be actively encouraged. This development will be across the spectrum of areas where Japan is at the world forefront and in those fields where Japan now lags behind the major industrialised nations.

In the first place, the Japanese Government is expected to actively pursue science and technology policies. The policy basis was outlined in *The General Guidelines for Science and Technology Policy* endorsed by a Cabinet Decision in March 1986. The *Guidelines* emphasise the importance of 'encouraging basic, leading sciences and technologies in which new progress can be expected' as one of the major policies in order to promote a highly creative environment for the continuing development of science and technology. The *Guidelines* lists the following as areas requiring encouragement:

(1) Investigating the limitations of the existing technology in dealing with matter, energy, information and other basic factors involved in science and technology; looking for and unveiling new principles and phenomena; and exploring new possibilities in science and technology exceeding the bounds of existing technology.

(2) Investigating life phenomena by taking advantage of the latest developments in molecular biology and

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23 Takemochi Ishii, *Nihon no Sentan Gijutsu* [Japanese High Technologies], (Nihon Hoso Shuppan Kyokai, Tokyo, 1985), pp.14-20.

related areas; and, looking for possible applications of the new knowledge.

(3) Acquiring better insight into *homo sapiens*, earth, outer space, marine resources, and other macroscopic entities in the environment around us, and looking for possible applications of the new knowledge.

For this purpose, the following areas of research were to be encouraged:

(a) Matter/materials sciences and technologies;

(b) Information/electronics sciences and technologies;

(c) Life sciences;

(d) Soft series of sciences and technologies;

(e) Space sciences and technologies;

(f) Marine sciences and technologies; and

(g) Earth sciences and technologies.[24]

The Ministry of International Trade and Industry has established a *Research and Development Project on Basic Technologies for Future Industries* to encourage research in the revolutionary basic technologies essential to the establishment of new manufacturing industries within the next generation. The Agency for Industrial Science and Technologies (MITI) is conducting basic research, in cooperation with universities and private firms, relating to the so-called technological seeds in new materials: biotechnologies, new electronic devices and superconductivities. Forty projects including superconductive materials and electron devices, high-performance ceramics, and 3-dimensional integrated circuitry are now underway.

The Japanese Government is expected to continue to promote research and development in the new technologies. The leading role of the Government is expected, in particular, in major research projects such as space, including the development of launch vehicles, and satellites as well as participation in the Space Station program; nuclear

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24 Prime Minister's Office, *Cabinet Decision: General Guidelines for Science and Technology*, (Tokyo, 28 March 1986).

energy (including fast-breeder reactors); nuclear fusion and high-level radioactive waste management; and development of the resources of the marine environment.

The private sector is expected to continue to be the main promoter of R&D activities in Japan. Some 80 per cent of the total expenditure of R&D in Japan is financed by this sector. The ratio of R&D expenditures by the private firms to gross sales has been steadily increasing in recent years: 1.78 per cent for 1982, 1.97 per cent for 1983, 1.99 per cent for 1984, 2.31 per cent for 1985 and 2.57 per cent for 1986.[25]

The increase in this ratio can be observed in each major industry, although the proportion does vary. The ratio for FY 1987 was 0.31 per cent for the agricultural sector, forestry and fishery industry; 0.51 per cent for the construction industry; 0.64 per cent for petrol and coal product manufacturing industries; and, 0.77 per cent for the pulp and paper manufacturing industry. In the higher range: 5.61 per cent for the electrical machinery manufacturing sector (5.78 per cent for the communication and electronic equipment industry); 4.91 per cent for the precision instrument manufacturing industry; and 4.53 per cent for the chemical product manufacturing industry (6.96 per cent for the drugs and pharmaceutical products industry). On the whole, high technology industries seem to spend more on research and development and, moreover, the ratio in such industries is increasing year by year.[26]

Intense competition is common to Japanese industry. Private firms are expected to continue to compete with one another in research and development, vying for products which could support future growth industries and those which could yield greater profits. As such, the ratio of R&D expenditures to gross sales will continue to rise.

Tasks for Japan

From the international standpoint, Japan should seek to strengthen its involvement in basic reseach in new technologies and encourage the development of international linkages.

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25 STA, *Kagaku Gijutsu Hakusho*, p.39.

26 MCA, *Kagaku Gijutsu Kenkyu Chosa Hokoku*, p.45.

(i) *The Strengthening of Basic Research Activities*: Japan spends relatively little in the field of basic research. One of the main reasons is the low level of government expenditure supporting R&D activities in universities—the focal area of basic research.

Japan has been subject to international criticism because of its poor performance in basic research activity. For example, during the course of negotiations on the revision of the Japan-U.S. Science and Technology Cooperation Agreement, U.S. representatives expressed their discontent with what was seen as Japan's inadequate level of investment in basic research activity. Japanese researchers, the U.S. side argued, undertook basic research within the U.S. universities and research institutions. These institutions had invested significant funds which Japanese researchers were able to utilise without cost to Japan. Researchers then tended to return to Japan and used the skills, funded by the U.S., for applied research producing commerially competitive products.[27] The U.S. criticised Japan as 'free riding' on basic research.

Taking this into consideration, the Japanese government is now adopting a policy to better promote basic research. *The General Guidelines for Science and Technology Policy* stipulate that:

> especially, we should concentrate on encouraging basic research to pave the way for technological progress in the next generation. Steps should be taken to create technological seeds to encourage further studies and reviews of theories, principles and phenomena. These will facilitate a more creative and imaginative science and technology environment capable of exceeding the bounds of mere modification and improvement by combining such seeds with the emerging social needs.[28]

The Science and Technology Agency established the Frontier Research Programs in 1986 to examine the technological seeds which could be the catalyst of a strategic breakthrough rather than needing to

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27 Ministry of Foreign Affairs (MFA), *Gaiko to Kagaku Gijutsu Task Force Hokokusho* [Report of Task Force on Diplomacy and Science and Technology], (Tokyo, 1989), p.4.

28 Prime Minister's Office, *Cabinet Decision: General Guidelines for Science and Technology*, 28 March 1986.

depend upon a flow-on from an existing technology. Such research is undertaken by groups of scientists from many disciplines working throughout Japanese industry, universities, government research institutions; and from overseas in existing research facilities in private research institutions. The main projects for FY 1987 included the bio-holonics project; the solid surface project; the quantum magneto flux logic project; and, the molecular dynamic assembly project.[29]

(ii) *Promotion of International Cooperation*: As research into new technologies has gained a higher profile, Japanese researchers have developed linkages with the international community. While expectations of Japanese technological research are high, a sense of caution and even of crisis becomes probable. Since technological innovation is a basis of industrial activity, competition is inevitable. On the other hand, it is important for Japan to promote international cooperation in the field of research and development in order to contribute to international economic development and avoid international friction. Such cooperation can develop both from a commercial basis and that of intergovernmental technology arrangements.

The first category of international cooperation is the transfer of technology on a commercial basis. Some current statistics on the present status of the Japanese technologies trade are as follows:

(a) The receipts received by Japanese industry through technologies export were ¥215.6 billion in FY 1987. The total payment through technologies import by industry was ¥283.2 billion, amounting to the deficit of ¥67.6 billion. Exports have increased between 1982 and 1984 but have been declining since 1985 while imports have fluctuated.

(b) Japanese industry received in FY 1987 some ¥44.8 billion as a result of new contracts concluded, and paid ¥56.2 billion, leading to a ¥11.4 billion deficit. The level of receipts increased in 1983 and 1984, but has been decreasing since 1985. Correspondingly,

29 STA, *Kagaku Gijutsu Hakusho*, pp.257-262.

payments decreased in 1983 and 1984 and increased after 1985.

(c) By sector of performance, the motor vehicles industry received ¥46 billion (accounting for 21.3 per cent of the total). The communication and electronic equipment industries; the electrical machinery, equipment and supplies industries; the industrial chemicals and chemical fibres industries; and the drugs and pharmaceutical products industry received ¥39.8 billion, ¥21.3 billion, ¥18.9 billion and ¥16.1 billion respectively. These five industries accounted for 65.9 per cent of total receipts.

The communication and electronic equipment industries received by far the largest amount of ¥75 billion (accounting for 26.5 per cent of the total payments). The electrical machinery and the equipment and supplies industries; the industrial chemicals and chemical fibres industries; the drugs and pharmaceutical products industry; and the motor vehicles industry were paid respectively ¥34.5 billion, ¥14.9 billion, ¥13.6 billion and ¥8.4 billion. These five industries accounted for 51.7 per cent of the total payments received.

Among these, five major industries (the communication and electronic equipment industries; the electrical machinery, and the equipment and supplies industries) were in deficit, while the motor vehicles industry; the industrial chemicals and chemical fibres industries; and the drugs and pharmaceutical products industry were in surplus.

(d) By country, Japan received from the U.S. the largest amount of ¥65.9 billion (accounting for 30.6 per cent of the total exports) followed by ¥27.5 billion (12.8 per cent) from South Korea, ¥21.7 billion (10.1 per cent) from China including Taiwan, and ¥10.6 billion (4.9 per cent) from the United Kingdom.

> As payment to cover imports, Japan paid the largest amount to the US—¥178.6 billion (accounting for 63 per cent of the total payments), followed by ¥22.1 billion (7.8 per cent) to France, ¥21.4 billion (7.6 per cent) to West Germany, ¥20.8 billion (7.3 per cent) to the Netherlands, ¥17.4 billion (6.1 per cent) to Switzerland and ¥10.3 billion (3.6 per cent) to the United Kingdom.[30]

As mentioned earlier, in the technologies trade, Japan is on the whole a net importer both by contract and by value. Continuing growth in the technologies trade enabled Japan to become a net importer (in terms of payment) after a 16 years interval in FY 1987 although the country remains a net exporter in the value of contracts concluded.[31]

Although the technologies trade is basically conducted on a commercial basis and is thus highly competitive, the increasing expectation for technology transfer from Japan should be taken into account. As Japanese technology continues to develop, and as the corporate strategies of Japanese companies become more globally oriented, the export of technology from Japan will increase. At the same time, we should promote further technical cooperation with the developing countries.

The second aspect of international cooperation is the opening of the Japanese research system to the outside world. During the negotiations on the revision of the Japan-U.S. Science and Technology Cooperation Agreement, the U.S. side pointed out that while American universities and research institutions accepted a great number of Japanese researchers, Japanese counterparts had accepted only a limited number from the U.S. The U.S. asked that this imbalance be rectified.

At the same time, the U.S. side advanced the argument of so-called symmetrical access. The U.S. noted what it saw as unfair competition. While basic research, in which the U.S. had a competitive edge, was conducted in universities and laboratories to which easy

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30 MCA, *Kagaku Gijutsu Kenkyui Chosa Hokouku*, pp.52-56.

31 *Ibid.*, p.52.

access is usually available, most of the applied research in which Japan has a competitive edge is performed by private firms to which access is often closed.[32]

With this situation in mind, the Japanese government is now advocating the development of an open-door policy to research, and is exerting great efforts to encourage the Japanese research system to welcome researchers from abroad.[33]

As an example, the Japanese Government has established several fellowship programs and invited as many as 210 foreign researchers to Japan in FY 1988. It increased the quota by 60 for FY 1989. The Government has also taken measures to enable international researchers to join in Japanese projects researching and developing in the field of new technologies. Under these Frontier Research Programs a Swedish scientist participated in the bio-holonics project; scientists from the U.S., France, Canada and Taiwan participated in the solid surface project; and Italian and Hungarian scientists participated in the molecular dynamic assembly project.

The third category of international cooperation is proposing and participating in various international projects. International cooperation is particularly desirable in fields where the projects' outcome would enhance global welfare and where a huge financial commitment is required.

The Japanese Government proposed the Human Frontier Science Program (HFSP) at the Venice Economic Summit Meeting in 1987. HFSP is an international program seeking to promote basic research focussed on understanding the sophisticated and complex mechanisms of living organisms for the benefit of humanity. The Japanese Government is now working out an appropriate framework for the implementation of the Program in cooperation with other Economic Summit participants—and hoped to start such activities as research grants, fellowships and workshops in the 1989 fiscal year.

Another example of international cooperation is the Space Station program. This program originates from President Reagan's initiative in January 1984 to develop, in collaboration with other

32 MFA, *Gaiko to Kagaku Gijutsu Task Force Hokokusho*, pp.4-6.

33 STA, *Kagaku Gijutsu Hakusho*, p.110.

countries, a permanently staffed space station. The Intergovernmental Agreement, which stipulates the terms and conditions of the cooperation, was signed in September 1988 by the U.S., the member countries of the European Space Agency, Japan and Canada. These countries will provide major elements of the Space Station as well as the crews who will conduct various experiments in the fields of material and life sciences and the celestial and earth observations which will utilise the unique character of the space environment.

JAPANESE TECHNOLOGIES AND ITS SECURITY POLICY

Since World War II, Japan, under its Constitution, has directed its efforts to the primary national goals of economic reconstruction and development. The ratio of its defence budget to either the total government budget or to its GNP has been relatively low compared with other major countries. Its ratio to the total government budget was 6.6 per cent in 1988 while the ratio was 27.1 per cent for the U.S. and 9.3 per cent for Australia in the same year.[34] The ratio of defence-related R&D expenditures to total government S&T expenditures also remained at a low level: 5.1 per cent in 1989.[35]

The development of Japanese technologies has led, in recent years, to an increase in Japan's potential capacity to develop and produce defence-related equipment. In particular, whilst the nuclear stalemate continued, more attention was paid to conventional weapons technology. At the same time, as the distinction between commercial and military technologies blurred, greater attention was directed to Japanese defence high technology in fields such as electronics and materials.

These developments have had implications both for East-West relations and for the intra-West security relationship.

In East-West relations, the transfer of Western high technology to the Eastern bloc attracted renewed attention due to the ready interchange of commercial technologies for military purposes.

In Japan, this tendency was highlighted by the the Toshiba Corporation incident in 1987. The Toshiba Machine Co., a subsidiary

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34 International Institute for Strategic Studies, *The Military Balance 1989-1990*, (Brassey's, London, 1989), pp.208-211.

35 STA, *Heisei Gannendo Kagaku Gijutsu Kankei Yosan*, pp.6-8.

of the Toshiba Corporation, had exported eight advanced milling machines designed to mill super-quiet submarine propellors to the Soviet Union in the period 1982-1984. The company had obtained the relevant export licences from the Japanese Ministry of International Trade and Industry by making a false application. The Japanese Government made a thorough investigation of this case in 1987. The company was fined, forbidden to export to the Soviet Union for a year, and two company executives were charged with company violations.

Although this was an unfortunate incident, it provided an important opportunity for the Japanese people, including its business leaders, to renew their recognition of the importance that the transfer of high technology equipment with a potential military application, be controlled. The Government, on its part, proposed an amendment to the *Foreign Exchange and Foreign Trade Control Law*. The amendment included tougher penalties as a deterrent, better enforcement, clearer specification of technologies subject to controls and the explicit stipulation that the Foreign Minister (in charge of security affairs), can state an opinion, if deemed necessary, when export licences are sought. The amendment was passed by the Diet in September 1987.

On the international scene, efforts are continuing through the cooperation of NATO member countries and Japan to maintain an effective level of export control within the framework of COCOM (Co-ordinating Committee for Multilateral Export Controls). Japan and the United States agreed to hold Japan-U.S. COCOM Consultations to exchange views on export control related matters. The first meeting took place in October 1987.

Over recent years Japan has become more involved in intra-West security relations, and developments in its high technologies have led to increased security cooperation between Japan and the U.S. Japan's Chief Cabinet Secretary issued a statement in January 1983, announcing that to effect the operation of the Japan-U.S. Security Treaty and its related arrangements, the Government of Japan had decided to enable transfer to the U.S. of military technologies notwithstanding the Three Principles on Arms Export.[36] In November the same year, Japan-U.S. arrangements on the transfer of military

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36 *Statement by the Chief Cabinet Secretary on Transfer of Military Technologies to the United States*, (Tokyo, 14 January 1983).

technologies to the U.S. were concluded. Under the arrangements, a Japanese firm (Ishikawajima-Harima Heavy Industries), has been transferring technologies concerning the construction and/or repair of U.S. naval vessels.

Japan also decided to participate in the U.S. Strategic Defense Initiative. In March 1985 the U.S. extended to its eighteen allies, including Japan, invitations to participate in this research program. In response, the Japanese Government clarified its position by issuing a statement from the Chief Cabinet Secretary in September 1986:

(i) The Japanese Government considers it appropriate to deal with the question of participation in the program in a way similar to that in which the exchange of defence-related technologies has so far been dealt with.

(ii) The Japanese Government has decided to enter into consultations with the U.S. Government on specific measures to ensure that the participation by Japanese private firms, etc., be carried out smoothly.[37]

After lengthy negotiations with the U.S., both governments signed the Agreement concerning Japanese participation in research in the Strategic Defense Initiative in July 1987, thus establishing a framework to ensure Japan's ready participation. In May 1988, the U.S. Department of Defense decided to conduct a study on the Western Pacific Missile Defense Architecture Plan as a part of its research under the SDI program. A consortium headed by Mitsubishi Heavy Industries is participating in this study, along with another consortium headed by a U.S. firm.

In addition to the instances cited above, requests for Japanese technologies and components by the U.S. Department of Defense will further increase. A report by the U.S. Under Secretary of Defense for Acquisition, entitled *Bolstering Defense Industrial Competitiveness*, admitted that 'many of the strategic industrial sectors that support the production of modern weapons systems are being threatened by intense, long-term competitive pressures from foreign producers.

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37 *Statement by the Chief Cabinet Secretary on SDI Research Program*, (Tokyo, 9 September 1986).

These include: semiconductors and semiconductor equipment, shipbuilding, automobiles, construction equipment, machine tools, flexible manufacturing systems, ball and roller bearings, castings, forgings, steel, and ceramics, to list a few.'[38] A report of DoD's Defense Science Board Task Force on *Defense Semiconductor Dependency* released in February 1987 stated:

> Although a number of technologies contribute in important ways to maintaining the strength of modern military forces, it is probable that electronics technology is dominant among these as a discriminator in combat capability.[39]
>
> ...Semiconductors are the key to leadership in electronics.[40]
>
> ...A number of examples were found...of systems containing semiconductors available only from foreign-owned, foreign-located sources. Even many of the 'so-called' domestic semiconductor devices incorporated in U.S. military systems can be traced to foreign countries in terms of the raw materials and processes involved in their manufacture—the latter including packaging and testing. A large share of integrated circuits are assembled and tested overseas. Ceramic packages are available almost exclusively from Japan—in this case from a single firm. One government-sponsored study of foreign dependency identified 16 components of foreign sources in one current air-to-air missile and concluded their denial would shut down production for up to 18 months.[41]

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38 Department of Defense, *Bolstering Defense Industrial Competitiveness, Report to the Secretary of Defense by the Under Secretary of Defense (Acquisition), July 1988*, (Washington DC, 1988), pp.26-27.

39 Department of Defense, *Report of Defense Science Board Task Force on Defense Semiconductor Dependency*, (Washington DC, February 1987), p.31.

40 *Ibid.*, p 39.

41 *Ibid.*, p.64.

It is becoming increasingly important for Japan to fully understand the security implications of its high technology sector, and to continue to employ these technologies for the promotion of Western security.

CHAPTER 3

TECHNOLOGY, DEVELOPMENT AND SECURITY: THE MALAYSIAN PERSPECTIVE

Zainal Abidin Haji Ahmad[1]

This chapter aims to provide an overview of the role of technology in the development and security processes in Malaysia within both a rapidly-changing international environment and within the Southeast Asian context. While the impact of technology on defence and security is well understood,[2] it is less clear what public policy should be in terms of the utilisation of technology (including appropriate technology) in terms of both defence and development purposes. Such a question requires complex considerations of financial viability and costs, the level of development (economic and knowledge-wise), political will, its contribution to national security and its consequences for regional order and security. And perhaps most importantly of all, there is the issue of how technology can be managed to enhance the security and defence of a country.

Like most other developing states, wherein the quest for national security is unremitting, the sense of security in Malaysia, faced with the onslaught of more powerful neighbours, not only numerically but also presumably those with more advanced or technologically sophisticated weaponry, is an awesome dilemma that

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1 The views expressed are those of the writer and do not necessarily represent those of the organisation with which he is associated. Dr Zakaria Haji Ahmad of the National University of Malaysia and Mr Krishnan Kutty of the Malaysian Ministry of Defence commented and contributed towards the drafting of this chapter. Their assistance is gratefully acknowledged.

2 John Garnett, 'Technology and Strategy', in John Baylis *et al*, *Contemporary Strategy, Vol. I*, (Croom Helm, London and Sydney, 2nd edn, 1987).

can divert scarce resources from the equally pressing needs of social and economic development. Acquisition of technology depends in large part, therefore, on political decisions concerning defence needs and requirements. Seen from this perspective, Malaysia, in its early years of independence under the leadership of Tunku Abdul Rahman, took a realistic approach to defence spending and acquisition.[3] However, since the late 1970s, there has been a more concerted effort to upgrade the country's defence capabilities, and in the process also to acquire technology know-how and advanced hardware.

It is clear that to be at the forefront of international competition, a country must continually develop new technologies. Such is the basis of technology policy in industrial countries. However, developing new technologies can require enormous amounts of financial and human resources; hence, for developing countries, one of the key elements of successful technology policy is to be able to acquire technology effectively from abroad and adapt it to local conditions and needs. This adaptive process is not easy since there is also the question of its absorption. It may also affect the indigenous development of technology, especially where it is neither well-understood nor widespread in terms of its application.

Technology acquisition and spread may or may not be congruent with the level of development. The examples in the Asia-Pacific region are quite disparate both in terms of experience and results. In terms of defence, as the examples of South Korea and Taiwan indicate, technology and defence industrialisation are related to the quest for self-reliance and lesser dependence on the supplies of allies.[4] In Indonesia, to take a contrasting example, defence industrialisation has proceeded well in certain sectors (especially aerospace) even though the level of economic development is not yet that of an industrial nation.

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3 See Zakaria Haji Ahmad, 'The Military and Development in Malaysia and Brunei, with a Short Survey on Singapore', in J. Soedjati Djiwandono and Yong Mun Cheong (eds.), *Soldiers and Stability in Southeast Asia*, (Institute of Southeast Asian Studies, Singapore, 1988), p.235.

4 Janne E. Nolan, *Military Industry in Taiwan and South Korea*, (Macmillan, London, 1986).

Against this background, I shall discuss the nature of public policy in Malaysia as it relates to civilian and defence technologies and its attendant ramifications for defence needs and the provision of security. In the latter section, I will evaluate the security environment and note how this interface with Malaysia's technology and defence policies is attempted.

In Malaysia development of new technology is linked with the country's economic growth. Until the early 1960s Malaysia's economic growth was based on the exploitation of the abundant natural resources and by offering incentives to foreign investors to develop labour-intensive export-oriented industries. The economy was dependent primarily on the export of commodities such as rubber, tin, palm oil and timber. But these commodities were subject to the volatile world market and during global recession the economy suffered considerably. Moreover, both the domestic and international economic situation imposed certain limitations on their future growth. As result it was realised that the country's strategy of economic development had to be shifted in the direction of establishing technology-based manufacturing industries.

With the government offering various incentives and the country possessing infrastructure facilities comparable to those of some industrialised nations, the last two decades have seen not only a significant increase in industrial production but also a certain measure of diversification of the industrial structure with the introduction and expansion of a variety of new and modern industries. To accelerate the industrialisation process the government launched the Industrial Master Plan (IMP) in 1986 to chart the nation's industrialisation options for the next decade. This Plan led to the formulation and implementation of a 'science and technology' policy attuned to the development of technological capabilities consistent with the envisaged expansion of and diversification within the manufacturing sector.

Malaysia, like all developing countries, must rely heavily on imported technology in order to achieve rapid industrialisation. However the experience of most developing countries has shown the practical difficulties of technology transfer. Even so, this is still the most practical means of developing technological capability as promoting new technology requires enormous amounts of financial and human resources which most developing countries cannot afford on the scale required. There has been, therefore, a realisation that there cannot be a 'quick-fix' formula for the introduction of technology for both developmental and defence objectives. On the other hand, the role of technology and investment in R&D does have a sense of urgency which should not be understated. One of the key elements of a successful policy is to be able to acquire technology effectively from abroad and adapt it to local conditions. Such strategies that use technologies from abroad very efficiently often yield much higher returns than those that concentrate on its initial development. Countries like Japan followed such a strategy relying at first on imported technology coupled with reverse engineering, and its adaptation and improvement.

The transfer of technology is a complex process which in essence entails three different stages: those of access, absorption and control. The transfer can only be achieved when the required skills, information and the technical excellence are effectively transferred, digested and indigenised. Any such transfer that does not result in successful commercialisation by local industry cannot be regarded as efficient. In this respect the creation of domestic research and development facilities is critical so as to be able to absorb, assimilate and develop an indigenous product.

In Malaysia, until recent years, the main emphasis in research and development has been to improve the productivity and output of the primary commodities which contribute most to the Malaysian economy. The more important of such R&D institutions are the Rubber Research Institute (RRI), the Malaysian Agriculture Research and Development Institute (MARDI) and the Palm Oil Research Institute of Malaysia (PORIM). However, realising the need for industrial research and development and the imperative to have access to sophisticated technology over a wide range of industries expected to be developed during the next decade, the government has in recent years tasked a number of ministries, statutory and non-statutory agencies and also advisory bodies to advise, coordinate and implement the science and technology policy of the country.

Among the ministries involved is the Ministry for Science, Technology and Environment, which is charged with the responsibility to develop and promote expansion of science and technology, to formulate resource plans and to determine that the application of science and technology does not give rise to any adverse effects, in particular to ensure that it does not lead to environmental pollution and destruction of wild life and plants. Other ministries involved are the Prime Minister's Department and the Ministry of Trade and Industry. In 1988 0.98 per cent of the GDP was spent on research and development and the bulk of this came from the public sector.[5] The private sector only contributes about 10 per cent of the total amount spent for research and development even with the various taxation incentives provided by the government.

The dearth of private sector research and development has led to the establishment of a number of government institutions to take up the slack, as it were, each basically geared to promote the establishment of modern technology-based industries. One area which has been given particular emphasis is that of microelectronics.

In Malaysia the electronics industry has, in a span of less than twenty years, grown from negligible proportions to a multi-billion *ringgit* activity of the nation. Malaysia is now the largest producer of integrated circuits and also the third largest producer of semi-conductors in the world. The bulk of the electronics industry has been centred around the component sector, which is currently producing resistors, capacitors, single-sided printed circuit boards, flyback and other transformers, deflection yokes and relays. Although over the years Malaysians have accumulated experience and expertise in semi-conductor assembly which could be employed in the use of robotics and Computer Aided Manufacturing (CAM) equipment, the industry continues to remain skewed towards the production of semi-conductors.

Realising that proper stimulation would be needed to enable the microelectronic industry to grow at a rapid pace in the right direction, the government established the Malaysian Institute of Microelectronics (MIMOS) in 1985. Its main objectives are to undertake and conduct research, to contribute towards the creation of an indigenous pool of experts in microelectronic systems, and to encourage and support the creation of new industries based on high technology and modern microelectronics.

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5 *New Straits Times*, 30 October 1989.

To cater to the various areas of microelectronics that are considered to be most significant, MIMOS has created four R&D divisions: viz. Computer Systems, Computer Aided Design, Industrial Projects and Information Technology. The Computer Systems Division has been set up to play a significant role in the development of an indigenous computer industry and to conduct R&D in areas related to computer hardware and software systems design, as well as in the application of microprocessors and microcomputers. The complexity of integrated circuits has increased at such an enormous rate that it is already possible to fabricate over a million transistors on a single chip. Although complete systems on a single silicon chip can be built, the design of the VLSI (Very Large-Scale Integration) chips is both extremely expensive and time consuming. The only solution is to create new CAD tools that are capable of performing design tasks automatically. Hence the CAD division conducts R&D in state-of-the-art methodologies so as to produce new generation CAD tools. The Industrial Projects Division conducts R&D in the application of microelectronics and VLSI systems in the industrial and consumer fields and also provides systems-design and prototyping expertise by translating basic ideas from industrial clients into cost-effective working prototypes. The Information Technology Division conducts R&D in the field of information technology, in particular in the areas of office automation systems, videotex, teletex, integrated voice-data cellular radio and others. MIMOS acts as an interface between technologists, government personnel and industrialists in order to achieve the common goal of a viable idigenous electronics industry capable of competing successfully in the world market.

The electronics industry has to a certain extent succeeded in adopting the reverse engineering process. Malaysians have successfully designed a number of portable radios, pagers and state-of-the-art (microcomputer-controlled) telephones for the international market. A number of technological breakthroughs have also been achieved in wafer manufacturing.

Apart from MIMOS the government has also set up a Technology Park in Cheros, a new and thriving suburb of Kuala Lumpur, to foster the growth of high-tech industries. Launched in 1988 the Malaysian Technology Park, through its incubation centre, encourages and offers facilities to small-scale industries to develop new technology. Typical of the new start-ups, the tenants of this Park are not into expensive high-tech projects or developing new ground-breaking products, but making and improving existing products using their own designs and technical know-how. Many of their innovations have import substitution and export potential. Among the companies situated in the Technology Park are ones involved in manufacturing personal computers and printed circuits while another is manufacturing computer disks. Some of the others are involved in software development, manufacturing personal computer interface cards, wireless headphones for television and video cassette recorders, direct point-to-point communications systems and a rural communication system for semi-permanent sites. While technology parks may not be the 'miracle pill' for industrialisation, they play a role by providing facilities in universities as well as R&D institutions. By doing so, entrepreneurs, researchers and innovation join hands in developing or commercialising ideas. As ideas alone will not be sufficient, technology parks provide venture-capital funding to turn ideas into products. For Malaysia technology parks are seen as a step in the right direction and a way to nurture home-grown technology.

Apart from the electronics sector we have also, to a certain measure, developed technological know-how in the field of aerospace. Realising its strategic value and economic importance, the government established the Aerospace Industries Malaysia (AIM) to spearhead the growth of the nation's aerospace industry. Subsequently a subsidiary company, AIROD Sdn Bhd, was established as a joint venture between AIM and Lockheed Aircraft Services International. AIROD seeks to provide medium and high technology service for aircraft, engines, components, accessories and avionics. The joint venture has four Divisions, viz. the Aircraft Division, Engine Division, Aero-components Division and the Avionics Division. The Aircraft Division performs depot-level maintenance, inspection, modifications, refurbishment, corrosion control, repair and operational checks for fixed wing, cargo, fighter, transport and rotary wing aircraft. The Engine Division undertakes overall inspection, repair and testing of turbo-jets, turbo-shafts and reciprocating-engines and their related accessories. The Aero-components Division carries out overhaul, repair and functional testing of gearboxes, transmissions, hydraulic systems and their related components. The Avionics Division performs repair and maintenance work for civil and military avionics and electronic equipment. It also calibrates and repairs electronic and mechanical precision-measurement equipment. As a leading aerospace centre in this country AIROD has the opportunities to establish the pace in specialised engineering skills and, with orderly transfer of technology, good foresight and a pragmatic approach, this facility has the potential to become one of the major aerospace centres in this part of the world.

Another recent development is the setting up of the Malaysian Centre for Remote Sensing (MCRS) which will be operational soon. Malaysia is a relative newcomer to the field of satellite remote-sensing compared to many countries in the region. Earlier attempts to enter the field had failed due to the lack of local expertise to analyse the data, and because of inherent limitations in the satellite systems then available. Hence the analysis of satellite remote sensing data has all this while been limited to a few research institutions and universities. However, recent developments in remote sensing data, in particular the successful commission of second generation satellites, resulted in renewed interest among the policy makers in the country. The MCRS will make it possible to extract data on environment and natural resources provided by the international satellite systems. The analysed data will, among other things, help in the planning and management of our natural resources as well as in agricultural and industrial development. The data to be analysed would be provided by international satellite systems such as the U.S. LANDSAT, the French SPOT and the new Japanese MOS I through the earth station near Bangkok.

The Centre is being set up under the Canadian Technical Aid program and will be operated mainly by local professional and semi-professional people trained in France and the Bangkok-based Asian Institute of Technology. It will be managed by the National Remote Sensing Committee comprising representatives from relevant government agencies including the Ministry of Defence. The military applications of remote sensing are well known and hence the setting up of the MCRS is of particular interest to the Malaysian Armed Forces.

The preceding comments on new technological developments in the fields of electronics, aerospace and remote sensing are of particular importance to the future development of the nation's defence industries. With electronics playing an increasingly important role in modern warfare, the development of a high technology electronics industry is, without doubt, of vital importance to the defence sector, not only to enable us to master the intricacies of modern weapons but to also innovate and develop our own weapons systems. The aerospace industry on the other hand is one of the fastest growing industries in the world today. Not only is it a potential revenue earner but its development is also of strategic importance to the country.

The emphasis we have placed in the areas mentioned so far do not, however, mean that technological developments in other industries are of lesser significance. On the contrary, a great deal of innovation and development is taking place, especially in the resource-based industries. Notable developments have taken place in the rubber industry which has moved on from the production of tyres for cars and commercial vehicles to the production of new and retread aircraft tyres and is currently the only country in the world capable of producing retread tyres for the Boeing 747-400 aircraft. This industry also produces a host of other products like rubber gloves, hoses, bushes, etc. A few companies are currently studying the feasibility of producing defence-related items and tests are being carried out on runflat tyres, dockyard fenders (for the naval base) and tank-track-links with rubber pads. The success of the rubber industry in such applications is mainly due to the excellent R&D facilities available at the world-famous RRI.

The production of road transport equipment is another industry which has undergone several stages of development. With the launching in 1983-84 of the 'Proton Saga', the national car project, the industry is slowly moving from the assembly phase towards the local manufacture of motor vehicles. Likewise, while mention can be made of many other areas of development, suffice to say that not only is Malaysia industrialising at a rapid pace, but it is also developing a broad industrial base and gaining technical expertise in varied fields.

It must, however, be admitted that while the civilian industrial sector has grown rapidly over the last few years, the same cannot be said for the defence industry sector. Malaysia's defence production facilities are still under-developed and except for a government-owned small arms ammunition factory, armed forces workshops (for basic maintenance and repair), a naval dockyard, and the joint-venture

AIROD Sdn Bhd, we do not possess any other substantial production facilities. However, this scenario is expected to change with the present policy of upgrading the defence capabilities of the Malaysian Armed Forces (MAF) and at the same time attain a certain level of self-reliance in defence equipment which will also complement the nation's desire to industrialise and acquire technological competence.

The Malaysian Armed Forces are currently at an important junction in their evolution. The force level and emphasis in strategic policy has shifted from that of a primarily internal security or counter-insurgency force to one with the conventional capability to defend the country from external threat. The modernisation of the MAF was in fact mooted many years ago, but only got underway in the early 1980s through the *PERISTA* [special expansion] program. Overall, the modernisation phase of the MAF has stressed two elements: the acquisition of new weapons and the development of local defence production facilities. In line with this policy, a National Defence Production policy was formulated in 1982 in which defence items classified as strategic, non-strategic and essential were to be produced over a period of years. This policy recognised the need for self-reliance in some basic requirements, with the government undertaking the production of strategic items and leaving the non-strategic and essential items to be produced by semi-government agencies and the private sector.

However, the onslaught of the recession in the mid-1980s not only led to the shelving of plans to acquire new weapons and slowed the introduction of *PERISTA*, but also affected the project funding as the government began to reduce defence allocations. The extent of these cutbacks can be seen from the fact that, whereas in 1982 1.64 billion ringgit was allocated as development expenditure to the defence sector, the allocations were drastically reduced until they fell to 152 million ringgit (constant prices) in 1987, the latter representing a mere 2.2 per cent of the overall development expenditure. The general slowdown of the economy also led to a lack of interest among local companies to undertake the production of defence items. Thus, during these years no new government-owned defence production facility was established. However, the turnaround of the economy from 1987 onwards has rekindled the interest of local companies, and even foreign ones, in the possible production of defence items. Meanwhile there has been a policy change whereby the government is more inclined towards privatisation and corporatisation. This is with the hope that such a policy would not only lighten the financial burden on the government but would also be a source of revenue. In line with this policy the government is currently encouraging the private sector to be involved in the setting up of production and maintenance facilities to meet Malaysia's defence requirements.

The defence industry is a good source of high technology and one way to obtain such technology is through procurement exercises. However, a strong industrial base is necessary to realise the technology transfer such procurements can bring about. With the country moving towards rapid industrialisation, Malaysia is now in a position to absorb an increased level of defence technology. The establishment of civil and defence industries must be viewed as a whole, as some civilian industries can be rapidly adapted to defence production. This area of overlap, dual-use technology, represents one of the more viable paths to local defence production in Malaysia. The automotive industry, for instance, can be readily adapted to produce military trucks and even tanks. Manufacture of civil electronic equipment can be switched over to the production of proximity fuses, surveillance equipment, etc. The electrical industry can manufacture aeronautical and naval electrical systems while the ship-building industry can be adapted to produce warships. This is the policy Malaysia is adopting as the consumption by the security forces is too small to establish facilities solely for defence production. Thus, the emphasis is to encourage companies engaged in the production of commercial goods to set up an additional line for defence items not only to meet the requirements of the MAF (and the Malaysian police), but possibly for export as well.

While Malaysia is still lagging behind most of its neighbours in defence production capabilities, the defence industry has received a shot in the arm with the proposed arms acquisition from Britain. In 1988, Malaysia signed a multi-billion ringgit Memorandum of Understanding (MoU) with the United Kingdom to acquire materiel and spare parts for our armed forces. While it cannot yet be disclosed as to what actual weapons will be purchased, some of the military hardware will include state of-the-art weapons systems like the

Tornado ADV and the ICS interdictor-strike aircraft,[6] air defence radars, ground-to-air missile launches, a C^3I system, and others. Apart from the weapons to be purchased under the MoU, Malaysia is also looking into the possibility of purchasing items such as short-range air defence missiles and other such equipment from suitable countries. It is anticipated that these purchases will ultimately involve some transfer of technology to Malaysia which would foster the growth of defence-related industries.

While these developments are taking place in terms of the introduction and upgrading of technology in Malaysia's defence requirements and situation, one must also be mindful of the implications of global and regional development and plans for regional security. The post-1945 arms race between Washington and Moscow in the world power stakes, reinforced as it was by advances in technological innovation, had unleashed the fear of Armageddon. As they entered the 1970s, both began developing the capability to obliterate the other and everyone else besides. With the expansion and intensification of the Cold War, technology added impetus every few years. The superpowers developed new weapons systems, multiple warheads were fitted to rockets, submarines carried missiles, and with the greater missile accuracy modern weapons now had enormous destructive power. In this power play the U.S., for four and a half decades after World War II, remained the unchallenged great power in this part of the region. Its withdrawal from Vietnam in 1975 set the stage for the emergence of the Soviet Union as a a power in Southeast Asia. This was evidenced by its maritime and aerial deployments in Vietnam, a development consonant with its military expansion in the Asia-Pacific region through the 1970s and early 1980s. Soviet support and aid for the Vietnamese who invaded Kampuchea in 1978 only made poignant the scenario of a changing balance of power situation in Southeast Asia (especially a situation of confrontation between ASEAN and the Indochinese states) and the real possibility of a denuded U.S. hegemony in the Asia-Pacific region. However, with the advent of Mikhail Gorbachev in the Soviet Union, the global situation in the mid-1980s has pointed to an easing of tensions between the superpowers, and an 'outbreak of peace' with the end of the Iran-Iraq

6 Editors' Note: In July 1990 changed to the BAe *Hawk* 100/200 aircraft.

war, Soviet military withdrawal from Afghanistan and in 1989 Sino-Soviet *rapprochement* and Vietnamese military withdrawal from Cambodia. The prospects of military confrontation, therefore, are less apparent in the decade of the 1990s.

Nonetheless, the international security situation, whilst retaining an element of strategic stability between the superpowers, is still one in flux. In the Asia-Pacific region, the rise of middle powers such as India and China, and the role of Japan as the U.S. loses its pre-eminence, are salient factors for consideration with respect to both national and regional security. The possible withdrawal of a U.S. military presence (and therefore its forward projection capabilities) from the Philippines in 1991 or thereafter will have an impact on the balance of power in Southeast Asia.

During the Vietnam War (the Second Indochina War), the majority of the Southeast Asian states did not need to worry about external threat as many of their problems were more internal in nature. Furthermore it was felt that any serious external threat could be dealt with by the U.S.. Ever since the defeat of the U.S. and the growing linkage between Vietnam and the Soviet Union the ASEAN states have realised that they could no longer be optimistic about seeking insurance from the Western strategic umbrella. The ASEAN states have come to realise that they must develop a degree of self-reliance so as to be able to cope with both their internal and external problems. Despite ASEAN's success in maintaining regional peace and stability since its inception in 1967 there are matters which underline the concern for security among the respective governments.

Territorial rights, competition for scarce and unexploited marine and undersea resources, incidents of contested sovereignty in the South China Sea and piracy have all contributed to anxieties about national and regional security. However, except for China and India, none of the other countries in the region have witnessed a phenomenal change in their weapons systems. India is by all definitions a superpower in the Indian sub-continent and one which has very dramatically expanded its military capability, including the acquisition of an impressive sea and aircraft capacity to project its military power. Apart from China, which is no less a regional superpower, the only other country in the region capable of achieving military supremacy is Japan, though it remains politically constrained for the moment. While none of the ASEAN countries has the hardware necessary to transform the nature of warfare, most of them, Malaysia included, are clearly enhancing their respective capabilities for a more independent and self-reliant defence posture.

Such an emphasis is more due to the increasingly complex and uncertain security situation in Southeast Asia, and not as a consequence of an arms race in the region. Military spending has generally been cautious among the ASEAN countries because they do not pursue national security solely in terms of obtaining military capability but emphasise national resilience through social and economic development and not the building up of large armed forces *per se*. However, it is a matter of political self-respect that the respective ASEAN governments undertake their own defence. Furthermore the Kuala Lumpur Declaration for a Zone of Peace, Freedom and Neutrality (ZOPFAN) in 1971 made it necessary for the ASEAN states to function militarily independent of external powers.

At the same time, it can be observed that Malaysia has not neglected security and defence arrangements with its ASEAN and non-ASEAN partners. Military cooperation in ASEAN has been primarily on a bilateral basis and can be expected to continue into the 1990s. One possibility is that such cooperation will extend to technology-sharing or joint production areas but this is subject to political factors and the complexities of ASEAN cooperation. But under the Five Power Defence Agreement (FPDA), the rotation of Australian F-18 aircraft sorties to the Malaysia/Singapore area and P-3C *Orion* maritime surveillance aircraft for South China Sea patrols do introduce elements of high technology which contribute to Malaysia's defence. However, viewed against the *desideratum* of ZOPFAN and the possible realisation of a Southeast Asia nuclear-weapon-free-zone (SEANWFZ), a greater emphasis can be expected from Malaysia to develop self-reliance in defence and technology acquisition.

Malaysia is strongly committed to the concept of military independence and it is precisely for this reason that it has embarked on the current arms purchases. Primarily, the latest purchase (as through the MoU) will enable Malaysia to project power into those areas of its sovereign jurisdiction, especially in the South China Sea where it has extensive hydrocarbon and marine resources, and in the protection of its land mass that is divided by this vital maritime and aerial space.

It may be perceived that two external developments over the next few years could affect Malaysian security, one being the withdrawal of the U.S. from bases in the Philippines and the other the territorial claims in the South China Sea. The spectre of maritime conflict in the South China Sea could be exacerbated by the reduced presence of the U.S. forces in Southeast Asia and the Western Pacific as a result of the U.S. Philippine-base withdrawal. In the South China Sea, Sino-Vietnamese military confrontation over the Spratlys may not be so easily contained and as such may have ramifications for Malaysian defence capabilities. The main defence concern is not only the claims over a number of islands but also enforcement of the country's 200 mile Exclusive Economic Zone where two of Malaysia's main resources—oil and gas—are located. Apart from this, the uncertainty over the future of the U.S. military commitment in Southeast Asia and the possible intrusion of other major power actors have also pin-pointed the need for Malaysia to look after its own defence needs.

Thus, seen in the context of these developments, it should be noted that the latest weapons purchase and the concomitant development of the local defence industry is not meant for offensive purposes but rather to upgrade this country's ability to protect itself. However, even with the need to upgrade our defence forces, Malaysia is in no hurry to purchase sophisticated hardware nor is there over-emphasis on diverting resources to the production of defence items. Malaysia's policy is rather one of selective purchase and the gradual development of local defence facilities. In the area of defence industry, no new technological developments are envisaged for the present and hence there is no race to develop sophisticated hardware. Such rationalisation may be observed as due to the fact that, first, as a developing country it cannot afford to divert resources to the development and production of sophisticated weapons and, second, because technological superiority is not necessarily viewed to mean a military advantage.

With all their technological superiority and awesome arsenals, the humbling of the two superpowers, the U.S. in Vietnam and the Soviets in Afghanistan, has brought home to many nations the lesson that technological supremacy does not necessarily win wars. It cannot, however, be disputed that over the years technology has had a strategic impact through new weapons which have changed power relationships on the battlefield and our century has seen a number of new technologies of significant strategic importance. Today, long-range aircraft and ballistic missiles have made homelands far away from the battlefield vulnerable to attack. Submarines have opened up the depths of the enormous ocean areas for military use and nuclear weapons have increased by many orders of magnitude our ability to cause devastation. Currently, among the main new technologies, three stand out as potentially revolutionary: guided missiles, fuel-air explosives and the systems required for simplified follow-on-attack. Even with these new weapons, it is undeniable that in ground warfare technological sophistication can, on occasion, be disadvantageous. Many of its features have no value in close terrain where mobility and range can be neutralised—exactly the kind of situation anyone waging war against any of the ASEAN countries would face. On the other hand, the rapid development of technology for the non-defence sectors of society has provided the basis for considerable industrial and economic change in many nations. Japan and West Germany for instance, two of the world's economic giants, have the potential to be major military powers should they so choose. Several newly-industrialised nations have achieved remarkable industrial and economic growth and are now capable of building sizeable arms industries. It is tempting though to want to develop a technological capability that is at least equal to potential adversaries and those of one's allies. Developments in conventional warfare technologies now mean that ballistic missiles with extended range and smart weapons are available in the market. Apart from political will, such acquisitions can be costly and have to be arrayed against other priorities and considerations.

The acquisition or introduction of technology is therefore a varied process which must be weighed against a national political and socio-economic environment. In Malaysia's case, the thrust is on social and economic development, required for it to become a highly industrialised nation within the next decade. With rapid industrialisation and the transfer of technology through the latest arms purchases, Malaysia could conceivably upgrade its military capability and be a defence-production industrialised nation. However, as has been said, Malaysia is not in the arms race but only seeks to be self-reliant for its defence, if not an independent military power. This should not, however, be interpreted as a lack of resolve or capability to meet force with force, especially as regards the nation's territorial sovereignty, maritime possessions and the legitimate extractive activities of its citizens.

At the same time, nevertheless, there is still an emphasis on cooperative endeavours with Malaysia's ASEAN partners. While the idea of a defence community has been suggested, albeit not including a military pact, Malaysia feels that ASEAN's collective military strength and that of the FPDA could be used against external threats, should the need arise. It is hoped that this will contribute to the overall stability and security of ASEAN and Southeast Asia in the long run.

In conclusion, it can be said that Malaysia is not unmindful of the role and impact of technology and its relation to defence and security needs, but it is only in the 1980s that aspects of policy have begun to take root in the context of objectives of national development. Nonetheless, technology is only one factor in a complex interplay of national, regional and international security. Malaysia seeks self-reliance in defence and a capability to meet potential threats (and to redress the technological lead of potential adversaries), but the pace has been thus far gradual and pragmatic.

CHAPTER 4

TECHNOLOGY FOR NATIONAL RESILIENCE: THE INDONESIAN PERSPECTIVE

A. Hasnan Habib

Indonesia entered the fifth and final phase of its First Twenty-Five Year Development Plan in 1989. *Pelita V* (the Fifth Five-Year Development Plan) is crucially important for the attainment of the overall objective of the Long-Term Plan, that is a firm and solid base from which to launch the Second Twenty-Five Development Plan (1993/1994-2018/2019) which is envisaged as the 'take-off period'.[1]

Since the first *Pelita* was begun in 1969/1970, Indonesia has undergone great changes which have made it very different from the nation that achieved independence in 1945. The metamorphosis has been the result of hard work, dedication and commitment to the realisation of the national goals constituting 'The National Interests', which are 'security and prosperity' (both in the broadest sense of the word) for the Indonesian people and the world.[2] The Indonesian people are more confident now than at any time in the past, ready to face the future which holds as many promises as it does challenges to make it work.

The experience of modern industrial societies has shown that technology has been the critical factor in their long-term economic

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1 Republik Indonesia, *Recana Pembangunan Lima Tahun Kelima 1989/90-1993/94, Buku I* [Fifth Five-Year Development Plan 1989/90-1993/94, Book I], (Jakarta, 1989), pp.19-20.

2 Indonesia's national goals, as set out in the preamble to the Constitution of 1945, call for the establishment of an 'Indonesian government which shall protect the whole of the Indonesian people and their native country, advance the general welfare of the people, develop the intellectual life of the nation and contribute to world freedom, peace and social justice'.

growth. Technology has been and will continue to be the great engine of growth and change. Technology feeds on itself: one development leads to more technologies through the never-ending process of innovation and invention. This process covers the three stages linked in self-reinforcing cycles: first, the emergence of a creative idea; second, its application; and third, its diffusion through society which in turn helps generate further development.[3]

As technologies have become increasingly sophisticated and complex, in order to flourish they must be supported by science and research. To sustain long-term growth the output of technological activities, i.e. a product or a service, must be able to meet the needs of the society and stand the test of the marketplace.[4] With the rapid progress of science and technology, Peter Drucker has suggested that three fundamental changes have occurred in the world economy and market:

(i) the primary products economy has become uncoupled from the industrial economy.

(ii) in the industrial economy itself, production has become uncoupled from employment.

(iii) capital movements rather than trade in goods and services have become the engines and driving force of the world economy.[5]

The implications for any country, especially any developing country aspiring to be taken into account in the community of nations, are clear. To succeed in its national development effort and to realise its aspirations, in addition to hard work it must acquire science and master technology. In this endeavour human resources development plays a central role.

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3 See Alvin Toffler, *Future Shock*, (Bantam, New York, 1970), pp.25-35.

4 Ralph Landau and Nathan Rosenberg, *The Positive Sum Strategy: Harnessing Technology for Economic Growth*, (National Academy Press, Washington DC, 1986).

5 Peter F. Drucker, *The Frontiers of Management: Where Tomorrow's Decisions are Being Shaped Today*, (Perennial Library, Harper & Row, New York, 1987), pp.21-49.

This chapter attempts to discuss, in general terms, Indonesia's policy and strategy in the promotion and development of science and technology as an integral part of the overall national development in the pursuit of the nation's long-term goals and aspirations. Indonesia's concept of security will be first outlined, followed by a survey of its national development in which technology plays an increasingly important role. Next, Indonesia's policy and strategy in acquiring and developing science, research and technology will be discussed, including the meaning and the mission of 'strategic industries'. Finally, the institutional set-up of the whole subject will be outlined.

INDONESIA'S CONCEPT OF SECURITY

Ketahanan Nasional (*Tannas*, National Resilience)

The statement of national goals indicates that security and prosperity are inter-related. Moreover, they are interdependent and mutually supportive. Different than the old conventional concept that equated security with a nation's capability to defend its territory against external threats, Indonesia's experience since independence has shown that the term 'security' denotes and connotes all aspects of national life, i.e. ideology, politics, the economy, society, culture and the military. Indonesia's concept of security is, therefore, complex and multi-dimensional.

Security is a condition which satisfies individual as well as collective needs, and brings about a feeling of safety and certainty in the pursuit of individual, collective and national prosperity. Optimum security can only prevail in a prosperous environment free from abject poverty and from persistent injustices and inequalities. But the reverse is also true—an insecure environment impedes the pursuit of prosperity. Thus security and prosperity are interwoven and cannot be separated from each other.

These considerations led to the development of the concept of *Tannas* which denotes both the security and prosperity condition of the national community and depicts the nation's capability to deal with, and overcome, any internal or external situation which threatens its security and prosperity, or aspects of its ideological, religious, political, economic, socio-cultural, and military life. At the same time it represents the nation's capability to raise the level and quality of its

Tannas. Indonesia seeks to attain an ever-growing *Tannas* through national development to realise its national goals.

Security and prosperity also constitute the two avenues to *Tannas*. Depending on the type, form, scope and intensity of the threat, emphasis can be placed on either aspect of *Tannas*. The lower the level of the threat to the security of the nation, the more emphasis is placed on the prosperity aspect. This means the application of a broad range of policies for comprehensive national development: including economic growth, social justice, educational improvement, the advancement of science and technology, public health, political maturity, and ideological and spiritual enhancement which Indonesia embarked upon in 1969/1970.

Maintaining and strengthening national resilience requires continuous effort. This is particularly pertinent for Indonesia given its young and turbulent history as an independent and sovereign nation, its relative backwardness, and its unique make-up in terms of geography, demography, ethnology and culture. Indonesia is perhaps one of the most diverse societies in the world. It is the biggest country in Southeast Asia, it occupies a most important geostrategic position in the region and it is richly endowed with natural resources. Each poses a tremendous challenge to the development of Indonesia's *Tannas*.

Wawasan Nusantara (Archipelagic Outlook)

Directly related to *Tannas* is the concept of *Wawasan Nusantara*. As Indonesia is the world's largest archipelagic state, with a total land and water area, including its Exclusive Economic Zone (EEZ), of roughly ten million square kilometres, the country's outlook differs from nations that are largely physically contiguous. Because its water surface area is greater than its land area and because the seas have served to link the islands rather than separate them, Indonesians, from time immemorial, have referred to their country as *Tanah Air Kita* (Our Land and Waters).

Indonesia's susceptibility and vulnerability to foreign incursion, infiltration and intervention due to its strategic position in Southeast Asia and its archipelagic make-up, makes it imperative that all islands and seas in and around the entire archipelago be united as one entity, the unitary Republic of Indonesia. This perception, belief and emotion which Indonesians have for their country is called the

Wawasan Nusantara. It expresses the unity of both its land and sea areas. *Wawasan Nusantara* encompasses an understanding not only of the geographic unity of the nation, but also the recognition that Indonesia constitutes a single and unified political, social, cultural, economic and defence and security entity.

Hankamrata (Total People's Defence)

Based on *Tannas* and *Wawasan Nusantara* the military aspect of security is organised into the system of *hankamrata* (total people's defence or territorial defence). At its core is the preparation of the *Angkatan Bersenjata Republik Indonesia* (ABRI, the Indonesian Armed Forces) and the civilian population in such a way as to enable them to wage defence in depth, employing various means of both conventional and non-conventional warfare.[6] Among the most significant characteristics of the system are, first, that it is a manifestly defensive system and, second, that it is truly self-reliant, rejecting any military alliances.

NATIONAL DEVELOPMENT

During the first two and a half decades following its birth in 1945, Indonesia concentrated on the sociological and political aspects of nation-building, i.e. forging the many different ethnic entities into a single nation and imbuing the people with a spirit of self-reliance. This was in effect the intuitive implementation of *Wawasan Nusantara* as the concept had not then been formulated. This occurred in an unfavourable regional and international geo-political environment. The hostile environment was engendered, in part, by armed conflicts imposed by neo-colonialist powers on nations which wanted independence, and by the Cold War. It was a turbulent period of painful even traumatic experiences, which nevertheless in the end gave satisfaction for, and pride in, its successful outcome.

Comprehensive national development started in 1969 after political and economic stability had been restored in the wake of the abortive but bloody communist coup attempt of 30 September 1965. The first *Pelita* of the First Twenty-Five Year Development Plan gave priority to economic development.

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6 For a detailed description of the system see *Law No.20/1982, Defence and Security of the Republic of Indonesia*.

Within the economic field, the emphasis was on agriculture, while industrial development was devised to progressively redress the imbalances in Indonesia's economic structure. It sought to expand employment opportunities, increase non-oil and gas exports, save foreign exchange, and utilise more efficiently natural energy and human resources.

Pelita IV, which ended in March 1989, called for a significant industrial expansion in the general areas of machinery and basic metals, basic chemicals, and miscellaneous industries to increase the level of export income. Efforts were made to stimulate processing and manufacturing capability in order to generate a higher value-added economy. This meant the introduction and increased involvement of modern technology in Indonesia's national development.

The results have been satisfying. Indonesia has succeeded in moving its economy away from the over-dependence on oil and gas which prevailed from 1970 through to 1981. Increasing at the annual rate of 45.5 per cent at current US dollars during that period, its share in total export revenues reached a peak of 82 per cent in the financial year 1981. It declined to 40 per cent at the end of *Pelita IV*.[7]

Structural changes have occurred within the country's GDP. The role of the primary sector has declined from 53 per cent in *Pelita I* to 39 per cent in *Pelita IV* and is expected to further decline to 34 per cent at the end of the current *Pelita V*. Within the primary sector, agriculture has declined significantly from 45 per cent in *Pelita I* to 25 per cent in *Pelita IV*. The secondary sector on the other hand, although moderately, has increased its share from 13 per cent in *Pelita I* to 19 per cent in *Pelita IV* and is projected to reach 23 per cent at the end of *Pelita V*. Within this sector the role of manufacturing has grown from 9 per cent in *Pelita I* to 14 per cent in *Pelita IV*; the projected growth at the end of *Pelita IV* is 17 per cent. Finally, the tertiary sector has also grown from 35 per cent in *Pelita I* to 42 per cent in *Pelita IV*, and is expected to reach 43 per cent in the final year of *Pelita V*.[8]

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7 Sumitro Djojohadikusomo, *Perkembangan Ekonomi Indonesia Selama Empat Tahap Pelita 1969/1970-1988/1989*, (Congress of the Indonesian Economists' Association [ISEI], Bukittinggi, 29 June 1989), Table 17.

8 *Ibid.*, pp.8-9.

SCIENCE, RESEARCH AND TECHNOLOGY DEVELOPMENT

Five General Objectives of SRT Development[9]

The general view concerning Third World countries' efforts in the development of technology is that they are directed toward fulfuling the basic needs of the people, such as food, shelter and medicine.[10] Indonesia, however, since the late 1970s, while continuing to improve basic needs technologies, has moved beyond that. The development of Science, Research and Technology (SRT) has gained an increasingly important place in the overall national development of the country.

SRT development hopes to attain five general objectives:

(i) the fulfillment of the people's basic needs such as health, settlement and housing, food and nutrition;

(ii) development of energy and natural resources that are needed by the country and the people;

(iii) the implementation of industrialisation;

(iv) strengthening national defence and security; and

(v) the enhancement of the people's social, economic, legal, cultural and spiritual requirements.

These are four-dimensional objectives (land, water, air and space, and environment) which are formulated in the National Research and Technology Matrix.

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9 This section is based on various addresses and speeches by Prof. Dr B.J. Habibie, Indonesia's Minister of State for Research and Technology.

10 In her keynote speech at the opening of the 'ASEAN Science and Technology Week' in Manila on 30 January 1989, Philippine President Corazon C. Aquino said: 'For some of us in ASEAN, technology has taken a back seat to other priorities. The needs of the majority are still the basics of food, shelter and medicine. So that whatever technologies we have developed have been directed toward feeding and housing our teeming millions, keeping flesh and bone together'. *World Executives Digest*, April 1989, p.28.

The Matrix serves two major purposes. First, to focus SRT objectives to the specific sectors in science and technology which will most contribute to the value-added process in the context of national development and to meet the needs of the nation. Second, to direct the attention of the scientific community and the general public toward the objectives being pursued to develop science and technology throughout the economy.[11]

Some Basic Principles of SRT Development

Having an SRT Matrix is important but not sufficient. There are many constraints that need to be addressed. The most important is the inadequate availability of human resources in both quantity and quality. Thus it is essential to develop a 'science and technology community'. Scientists, engineers and other professionals, and their professional institutions, have been encouraged to optimise the use of scarce resources, monitor the cost and quality of what is being produced and foster international cooperation, particularly with the technologically advanced countries.

To effect this, certain principles must be taken into account:

(i) The level of literacy and education must be raised. Education and training in those fields of science and technology relevant to national development must be undertaken, both within Indonesia and abroad. As technologies become increasingly dependent on science, scientific literacy and science teaching at all levels becomes important. This calls for well-equipped laboratories and, in the present era of fast-moving science, the provision of the latest books and journals.

(ii) Technologies can only be transferred, adapted and further developed through their being applied to concrete problems. Technologies cannot be learned, let alone developed, in abstract. Only by working on

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11 *Principal Programmes on Research and Technology for Indonesia's Fifth Five-Year Development Plan 1989-1994*, (National Research Council Secretariat, Office of the Minister of State for Research and Technology, Jakarta, 1987).

concrete problems can a specific technology be comprehended in its entirety, thus enabling its further development. To develop rice-production technology, for example, rice agriculture and various rice-production technologies available in the world must be studied. But this alone is not sufficient. It must be followed by production under the specific soil, climatic, economic, social and cultural conditions within our country. These results would constitute the basis for innovation and the development of our own technologies. No country can afford to be a continuing importer of technology.

(iii) There is no such thing as appropriate technology for developing nations. A developing nation does not have to restrict itself to the kind of technology perceived to be appropriate and commensurate with its status as a developing country. A nation that denies itself the use of advanced technologies, such as remote sensing to map and inventory its natural resources, or modern health technologies to eradicate endemic diseases or to improve sanitary conditions, condemns itself to remain undeveloped.

On the other hand, if modern technology does not serve as a stimulant for national development, then it will inhibit rather than promote growth.

(iv) A national information system on technology must be established, developed, and connected to global information networks.

Strategy for the Acqusition of Advanced Technology

The strategy for the acquisition of advanced technology which involves transfer of technology and its further development consists of two elements: the phases of technology transfer, and the manner of its implementation.

Within the first phase, four inter-connected phases can be distinguished. The first and most basic phase is the application of existing technologies for value-added processes in assembling and manufacturing products or goods which are already on the market. In this phase, production and management technologies are used to transform raw materials and intermediate goods into higher-value finished products. The technologies for selected products are imported and produced under license. Progressive manufacturing programs must be devised to help ensure the systematic transfer of licensed technologies by relating the progression of transfer to the number of items produced.

Through this phase, advanced designs and manufacturing processes developed abroad can be obtained. Moreover, better manufacturing skills and management capabilities are developed, quality standards enforced, work discipline inculcated and the maintenance of discipline and quality standards becomes more widespread.

The second phase involves the use of existing technologies for the design and production of entirely new products not yet on the market. At this stage new designs and blueprints are developed, thus adding a new element, that of creativity. In addition to design capability, other skills are gained. These are skills in integrating and optimising components into the new systems, and the ability to select, from all the possible designs for components of the new system, those that will become the most optimal.

Every component derives its market value from its function in the total product or system, while the value of the product or system is determined in the market according to its functional use in the community. For example, no matter how well it is designed, an undercarriage system or propellor will not have any value in the market, unless it can be integrated into an existing or future railway wagon or aeroplane respectively. Components are marketable only when they can perform their function in end-products or systems which have their own particular function in society; in other words, when the product can meet the needs of the society.

At this stage opportunities are generated by the market for the emergence of new industries that produce components and other vendor items. Manufacturers of components will compete to offer their designs and products to those industries undertaking development work. Market forces will attract an increased flow of technological information into the country.

As the new product needs to be tested before each is marketed, testing capabilities will be further developed. The level of research and development facilities will thus expand, improving facilities for design, testing and simulation.

The third phase involves the development of new domestic technologies. Those in existence will be improved and new ones developed in the effort to design and manufacture products for the future. This is the phase of innovation, which is necessary for every firm or nation seeking to maintain its position in the market.

The fourth and final phase involves large-scale basic research to ensure that the country does not fall behind in the never-ending race for technological superiority. While some developing countries do invest in basic research, many find that their scarce financial, material and human resources are better spent in more urgent tasks. The great bulk of basic research is, therefore, undertaken in developed countries, whilst others maintain access to this research and its results through cooperative agreements in science and technology.

The second element of the strategy—the manner of its implementation—involves the selection of a particular product able to serve as a conduit for the transfer and further development of technology in Indonesia. In principle, any product can serve this function. Yet, in order to launch a developing country into a sustained process of industrial transformation the mode of technology transfer must accord with its unique circumstances, such as the size of its domestic market. Developing countries with a limited domestic market will have to enter the world market and compete with other producers of similar products. Obviously this is no easy task, particularly for the 'late comers'.

STRATEGIC INDUSTRIES

Strategic Industries and SRT Development

Paragraph 2 of Article 3 of the 1945 Constitution stipulates that 'branches of production vital to the State and governing the life and livelihood of the public shall be controlled by the State'. Article 4 of *Law No.5/1984* on *Industrialisation* designates such branches as strategic industries, if they are:

(i) crucial for the public welfare or govern the life and livelihood of the people;

(ii) produce strategic raw materials; and

(iii) linked directly with the defence and security interest of the country.

It also states that 'controlled by the State' does not automatically mean 'owned by the State', but rather that the State is empowered to issue and enforce regulations concerning their mission, production and management in the context of maintaining economic stability and growth and the enhancement of *Tannas*. They serve three purposes:

(i) to facilitate, on a continuous basis, the development of the economy and society;

(ii) to increase the nation's defence capability and promote its security; and

(iii) to function as conduits for technology transfer.

Strategic industries are therefore directly linked with the attainment of an ever-increasing *Tannas* and *Wawasan Nusantara*. The ability to maintain the integrity and unity of the archipelago as a political, economic, social, cultural, and defence and security entity depends a great deal on these industries. (The word 'strategic' is used here in its most comprehensive sense.)

Based on all the considerations mentioned above, the strategic importance of the transportation sector, namely the aircraft industry, the maritime and shipbuilding industry, and the rolling-stock industry, augmented by electronics, telecommunications and steel industries, is beyond any doubt. As incomes rise, and industrialisation progresses, the energy sector such as the manufacture of turbines, boilers, generators and heat exchangers will also become of strategic importance.

Defence Industries

Like most developing countries, Indonesia's military capability is directed to maintain internal stability and security, and to ward off the threats from its immediate neighbourhood, rather than to meet the requirements of external defence against a major power. An important reason for this is that, as a whole, developing countries are constrained by priorities of economic development and modernisation. This is not to say that Indonesia is helpless against a major external military threat. Its military doctrine, *hankamrata*, is the answer to that.

Despite the constraints, the trends in the developing world indicate a growing aspiration and ambition for military self-sufficiency. In this regard, Indonesia has also started on a very modest scale to establish its defence industry for the production of selected military hardware to meet some of its defence and security needs. However, they have not been set up exclusively for arms production. They are not a priority of the First Twenty-Five Year Development Plan, nor will they likely be in the Second Long-Term Plan.[12] And *hankamrata* does not make provision for an exclusive defence industry.

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12 ABRI did not start its first Force Development Program under the First Strategic Development Plan (*Renstra*) until *Pelita II* (1974/1975-1978/1979) which happened to coincide with the increase of state revenues due to the rise in oil prices in 1973. Firmly convinced of the need to prioritise the social and economic development of the country (or the prosperity aspect of *Tannas*), ABRI was directly involved in the formulation of the New Order Strategy. The Strategy enabled the top-echelon production and maintenance facilities such as the Army's Ordnance Depot and Munitions Factory, the Navy's Dockyard, and the Air Force's Aviation Industry, to be made available to the public. These were among the first designated strategic industries. That ABRI development was among the lowest priorities is evident from the development budget allocated to it through *Pelita IV* (1969/1970-1987/1988) totalling only Rp.4,584.6 billion (or 6.2 per cent) of the total national development budget of Rp.73,654.9 billion, in contrast to the Rp.43,650 bilion (or 59.3 per cent) for economic development. See *Nota Keuangan dan Rancangan Anggaran Pendappatan dan Belanja Negara Tahun 1988/1989*, (Bill on Income and Expenditure of the National Budget 1988/1989, Table II.1), p.23. During the first *Pelita* (1969/1970-1973/1974) ABRI carried out the 'Integration, Reorganisation and Consolidation Plan', involving not only the streamlining of its structure, but also the disposal of its heavy weapons systems and platforms which were too costly to maintain and operate, such as the *Irian Jaya* cruiser, the TU-16 strategic bombers, and the MIG-15 fighter aircraft.

What was envisaged was a strong national industry sector which could be converted easily to produce military hardware.

Although the main tasks of the strategic industries are to manufacture civilian products in response to consumer demand and to function as vehicles for the industrial and technological transformation of the country, virtually all their products have dual-use applicability. The aircraft, shipbuilding and rolling-stock and other land transportation equipment industries, for example, will all provide the infrastructure for the development of weapons and weapons systems platforms. With these industrial and technological developments, Indonesia's capability to develop its domestic defence industries toward selective self-sufficiency will also increase.

INSTITUTIONAL SET-UP FOR SRT DEVELOPMENT

SRT development[13] is handled by a number of state agencies under the overall management of the Minister of State for Science, Research and Technology. These agencies are:

Dewan Riset Nasional (National Research Council) was established by Presidential Decree No.1/1984 to direct and evaluate science and technology projects based on the National Science and Technology Matrix.

Badan Penelitian dan Penerapan Teknologi (BPPT, Agency for the Assessment and Application of Technology) was established by Presidential Decrees No.25/1978 and No.31/1982 to advise the President on matters of national policy with respect to the development and application of technology for national development. BPPT coordinates the implementation of technology development and application programs, provides advisory and consulting services to government agencies and the private sector, and implements technology development programs.

Its Chairman, who is concurrently the Minister of State for Research and Technology, is assisted by six Deputies, five of whom are involved in day-to-day research in the following fields:

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13 Suberti, Ninok Leksono, Mustoffa K. Ridwan and A. Makmuk Makka (eds.), *Teknologi di Indonesia*, (Cipta Kreatif, Jakarta, 1987).

(i) basic and applied sciences—life, engineering and marine;

(ii) technology development—human settlement and environment, industrial processes, energy conservation and conversion, electronics and information, and the related physical facilities and laboratories;

(iii) industrial analyses—machine and electro-technical industries, processing and engineering industries, strategic (including defence) industries, and related industrial infrastructure;

(iv) natural resources—both mineral and non-mineral; and

(v) systems analyses—operations research and management, technological regulation and simulation and modelling

In addition, the Agency operates the Construction Testing Laboratory; the Aerodynamics, Gas Dynamics and Vibrations Laboratory; the Thermodynamics and Propulsion Laboratory; the Energy Laboratory; the Processing Technology Unit; the Ethanol, Single-Cell Protein and Sugar Unit; the Hydro-electrical Unit; the Coal Processing Unit; the Transportation Systems Unit; the Defence Industries Unit; and the Social Sciences Unit.

Lembage Ilmu Pengetehuan Indonesia (LIPI, the Indonesian Institute of Science) was established by Presidential Decree No.128/1967, preceding the establishment of BPPT by more than a decade, to promote science and develop technology. It has attained notable achievements especially in the field of instrumentation which is of major importance in promoting industrial development, radio and telecommunication technology and electronics.

Badan Atom Nasional (BATAN, the National Nuclear Agency) was established by *Law No.31/1964* to implement, organise and supervise research into the application of nuclear energy for civilian purposes.

Lembarga Penerbangan Antariksa Nasional (LAPAN, the National Institute for Aeronautics and Space Technology) was established by Government Decree No.236/1963. It has built a number of high-utility research facilities, including the meteorology satellite earth stations at

Pekayon, Jakarta and Biak; telecommunications and telediffusion satellite earth stations in Bogor; a propellant and rocket engine laboratory at Rumpin; and a solar observation laboratory in Sukabumi. It has also experimented with a number of rockets and rocket fuels, and is cooperating with NASA (US), CNES (France), DFVLR (Federal Republic of Germany), and NASDA (Japan).

Badan Pengelola Industri Strategis (BPIS, Agency for the Management and Development of Strategic Industries) has been the most recent of the institutions created within the context of SRT development. Established by Presidential Decree No.44/1989, its mission is to manage and develop all state-owned industries which are designated as strategic industries. By the end of 1989 these were:

- *Industri Pesawat Terbang Nusantara* (IPTN, Nusantara Aircraft Factory);
- *PT PAL Indonesia* (Shipbuilding Industry);
- *PT PINDAD* (Small Arms, Munition and Heavy Equipment Industry);
- *PERUM Dahana* (Integrated Explosives Industry);
- *PT Krakatau Steel* (Steel Industry);
- *PT Industri Kereta Api* (INKA, Rolling Stock Industry);
- *PT Industri Telekomunikasi Indonesia* (INTI, Telecommunications Industry);
- *Unit Produksi Lembaga Elektronika Nasional Lembaga Ilmu Paengetahuan Indonesia*, (LEN-LIPI, National Electronics Institute formerly owned by LIPI); and
- *PT Barata Indonesia* and *PT Boma Bisma Indra*, manufacturers of machine tools, boilers, and an assortment of steel equipment.

The formation of the Agency has taken a long time, preceded by, first, a Team for the Development of Defence Industries, established by Presidential Decree No.40/1980. The Team was replaced by the Council of Ministers on Strategic Industries, established by Presidential Decree No.59/1983.

CONCLUSION

This chapter has sought to explain that technology in Indonesia is not pursued in isolation from the general developmental efforts of the nation. Nor is it motivated by the ambition to become a military power.

Indonesia, together with its ASEAN partners, aspires to see Southeast Asia as a Zone of Peace, Freedom and Neutrality (ZOPFAN), which will provide the countries in this region with the opportunity to pursue prosperity and security for their peoples. In other words, each country's *Ketahanan Nasional* (National Resilience) is the precondition of achieving *Ketahanan Regional* (Regional Resilience).[14]

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14 See the *Bangkok Declaration*, (ASEAN, Bangkok, 8 August 1967); the *Kuala Lumpur Declaration* [on ZOPFAN], (ASEAN, Kuala Lumpur, 27 November 1971); the *Declaration of the ASEAN Concord*, (ASEAN, Bali, 24 February 1976); and the *Treaty Of Amity and Cooperation in Southeast Asia*, (ASEAN, Bali, 24 February 1976).

CHAPTER 5

DEFENCE, TECHNOLOGY AND DEVELOPMENT—THE INDIAN EXPERIENCE

V.S. Arunachalam[1]

There is a sudden interest in Indian defence and technological capabilities with the test-firing of *Agni* in May 1989—a demonstration of an intermediate-range ballistic missile. While some nations have expressed surprise about the level of technological sophistication reached by India, others have reacted cautiously, voicing concern about the building-up of Indian military power. The test-firing of the *Agni* missile also provided an opportunity for the Indian Prime Minister to voice the country's determination to master technologies required for the nation's defences so that the India's freedom would never again be compromised.

What is India's security perception? What is the country's capability in defence and in other areas? How does India manage, or plan to manage, the indigenisation of its defence requirements? These are some of the issues I shall address in this chapter. I shall not discuss either the political or threat perceptions in any detail nor do I propose to describe various programs of defence technologies or their production. Instead, I propose to discuss the country's policy towards defence, national development and the rationale for the efforts to become self-reliant. This is a major issue as defence planning in India centres round the ability to become self-reliant in weapons and systems.

INDIA—THE LAND AND THE PEOPLE

India is a large country of almost continental proportions. It has a land area of 3.29 million square kilometres and a border running to 15,200

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1 The author is grateful to Mr S. Ramanujam and Dr P.C. Angelo for much stimulating discussion and assistance in preparing the article. He also thanks Dr V.K. Aatre, Director of the Naval Physical and Oceanographic Laboratory at Cochin, for delivering the paper at the Conference, in his absence.

kilometres which adjoins that of six countries. The coastline is long, 6,083 kilometres, with an Exclusive Economic Zone of 2 million square kilometres. But what makes India almost a continent is not just the size but the land and the nature of the people. The land is one of rich diversity in the north with snow-clad mountains, alpine valleys and fertile plains irrigated by the perennial rivers of the Himalayas. There are deserts, tropical forests and also a long peninsula of monsoon-fed tropical land. The people of India also reflect this diversity. The racial and ethnic mix is rich, each with its own culture and traditions. Even the languages are many although only fourteen are officially recognised. Within the terms of its Constitution, India is a secular democracy with Hindus, Muslims and Christians comprising the largest constituent parts. It may also be of some interest to know that today in India there are nearly as many Muslims as are in Pakistan.

India is a democratic republic with a central government, 25 state governments and 7 Union Territories. The government is elected to power on the basis of national and state elections held every five years, the most recent being the general elections for the central and some state legislatures held in November 1989.

INDIAN INDUSTRIALISATION

General Observations

This review of Indian industrialisation is concerned with developments in university-level technical education which provide India with necessary inputs required for the growth of its defence production capability. In 1947, when India became independent, GNP was 10,000 million rupees and the industrial sector was rudimentary. Even the annual iron and steel production, an indicator of sorts for evaluating the extent of industrialisation, was only a few hundred thousand tonnes. Independent India took some major political decisions in 1956 by accepting the concept of a mixed economy with both private and public sectors contributing to the industrialisation process.[2] The government reserved the sectors dealing with defence and core industries for itself and

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2 These decisions were promulgated in the *Industrial Policy Resolution 1956*. Two schedules were listed: A and B. Schedule A listed industries (including most defence industries) which were to be entirely government controlled; Schedule B listed those in which private enterprise could participate.

deregulated the remaining sectors to private capital. This led to the construction of the required industrial infrastructure without conflicting with the needs of private entrepreneurship and concurrently meeting customer demands. Without this mix, the industrialisation process in India would not have become as rich and widespread. Private ventures, at least during those days, were neither rich nor pioneering enough to invest in the core sectors of steel, petroleum or heavy industries with each requiring massive amounts of capital and returning only a modest profit. This joint approach has also shielded India from the excesses of public ownership with its attendant starvation of consumer industries. Individual entrepreneurship was encouraged and is now playing an ever-increasing role with the continuing liberalisation of government policy. Together this has led to a fairly impressive level of industrial growth. For instance, steel production currently stands at around 10.5 million tonnes per year and the ship-building sector has the capacity to build ships up to 100,000 dwt. India has also built up large chemical, petroleum and petro-chemical industries and off-shore oil production facilities which supply 67 per cent of the indigenous production. Figures 1 to 3 show GNP growth, power production (hydroelectricity, thermal and total) and saleable steel production over the years.

FIGURE 1
GNP (Market price in billion of rupees)

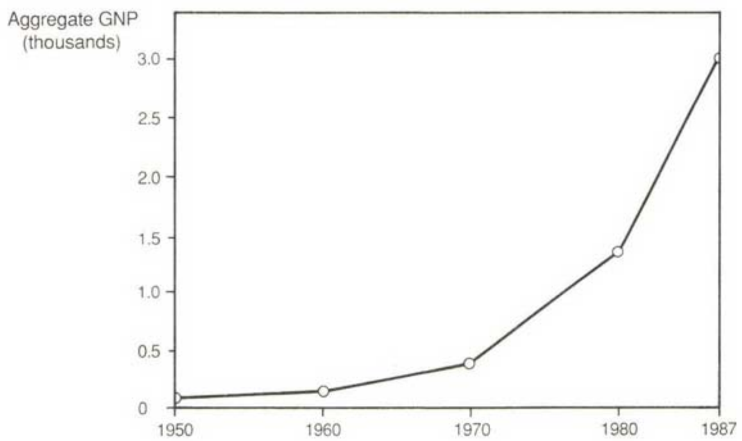


FIGURE 2
POWER PRODUCTION

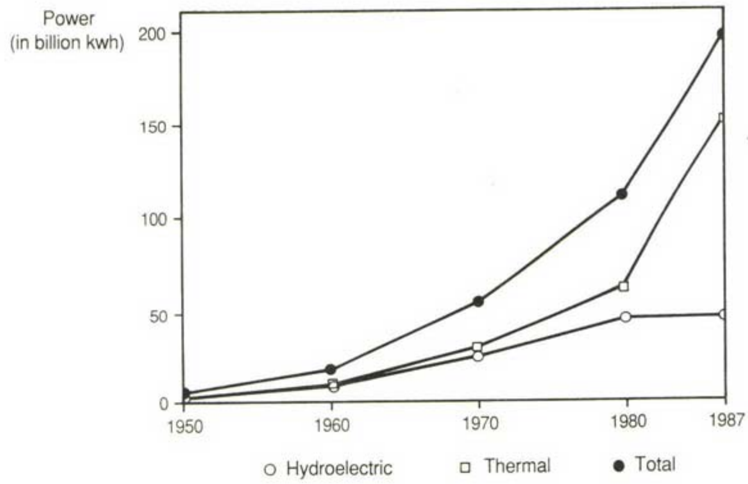
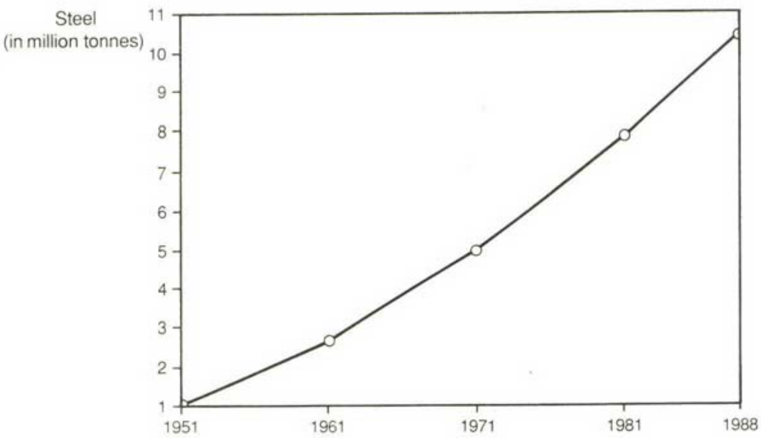


FIGURE 3
SALEABLE STEEL PRODUCTION



Advanced Technologies

But what is more impressive is the number of industries in the new technology field. The Indian electronics industry has developed the infrastructure to design, develop and manufacture silicon chips needed for many sophisticated applications. The same is true of the aerospace industries which manufacture fighters, passenger aircraft, space vehicles and satellites. India entered the space race by launching the first satellite with an indigenous rocket in 1980. This has been followed by the launching of a variety of satellites including a recent remote-sensing one (IRS).[3] The Indian space program continues to be vigorous with a plan to launch an indigenous geostationary communications satellite by 1993. In October 1989 India successfully tested a giant solid-propellant rocket booster weighing more than one hundred tonnes. In its size, capacity and thrust it compares well with the solid-rocket-booster of the US Space Shuttle.

The Indian nuclear energy program is older. Atomic energy laboratories were built in the mid-1950s and many industrial and technical centres related to these programs were established. Their interests included uranium, thorium, beryllium and zirconium extraction technologies and the production of power reactor fuels, heavy water, plutonium and fast-reactor fuels. From the very beginning, the Atomic Energy Program planned to be self-reliant and self-sufficient. This has proved to be very helpful in the establishment of the four nuclear power stations—in spite of embargoes on components and systems from the many countries which did not support India pursuing an independent nuclear policy. With its now well-established infrastructure in this area, India has plans for building more power reactors in the coming decade. There are also many research reactors in operation, including a fast-breeder test reactor using carbide fuel.

I have cited the above programs as examples that emphasise the Indian commitment to the development of advanced technologies which hold the key for industrial growth in the coming decades. RRather than attempting to catch up with industrially advanced countries step-by-step in an evolutionary way, India chose a route for industrialisation which

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3 Council of Scientific and Industrial Research, *Status Report on Science and Technology in India: 1988*, (Council of Scientific and Industrial Research, New Dehli, 1989), Table, p.34.

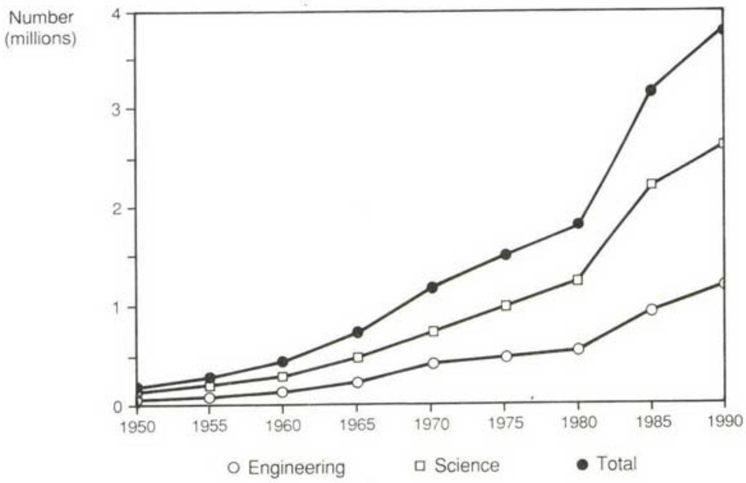
involved leap-frogging into selected new technology. Continuing adherence to this policy would not have been possible but for the strong and unwavering commitment to self-reliance from the political leadership. Starting from Jawaharlal Nehru, each of the prime ministers have withstood foreign, political and other pressures to bring India's high technology programs under other nations' scrutiny and control. Political leaders have continued to voice their belief that political freedom for the country remains a function of economic strength and the investment in advanced technology.

Technical Personnel—A Resource

Underpinning the growth of industry is the need to train personnel in the scientific and technological areas. There were only a few hundred students in engineering and technology in pre-independent India. Since Independence, universities and institutions of technology have so readily mushroomed that, today, India has more than 100 universities! Though academic standards in some universities are relatively modest, others possess standards comparable to the best of the Western universities. Indian universities and institutes graduate about 150,000 students per year in science and engineering disciplines and these people constitute the very back-bone for the entire Indian industrialisation and technology programs. Even though India loses a sizeable percentage of her graduates to other countries, the so-called brain-drain, a large number of them do stay and work in the country. An important aspect of this personnel growth is the variety and sophistication of specialisation. Opportunities are wide, covering such disciplines as aeronautical engineering to automation, robotics to artificial intelligence. Figure 4 indicates the number of science, engineering and total science and technology (S&T) personnel over the years.

Their availability has facilitated the continuing Indian industrial build-up after the first phase of industrialisation was achieved with the benefit of foreign expertise and advice. While many other developing nations chose the easier option of sending students to developed countries for training, India chose a more difficult route of training them at home and building facilities within its own universities. This is now paying rich dividends. If the first post-independence technical personnel studied or trained abroad, the second generation is home-grown and is in larger number, and what is more, brimming with confidence. The major

FIGURE 4
SCIENCE AND TECHNICAL PERSONNEL



breakthroughs in Indian technologies can often be traced back to these youngsters who learnt their skills at home.

SECURITY CONCERNS

An Historical Perspective

It is a truism that a nation is a prisoner of its geography and history, and perhaps India is an ideal case to underline this assertion. Indian history is replete with invasions from outside through the mountain-passes of the northwest. The list of invaders appears almost endless, starting with the Greeks under Alexander and ending with the British. Only the Europeans chose the sea-lanes for trading and only they occupied the Indian sub-continent. Every invasion left its mark, some ending with the settling of the invaders and their assimilation into the Indian milieu. They enriched the society but, also, divided it. There were new religions and forced conversions and the slow draining away of the genius of indigenous origin. This was seen even during the British occupation of India. They brought the products of the industrial revolution yet India itself remained largely untapped. Only a foreign addiction for every technology and its artifacts grew with industrialisation. There were notable exceptions though: India was introduced to Western science and technology and some outstanding contributions to the sciences came from Indian researchers. The importance of this movement should not be minimised as it is this base that served as the nucleus when India chose to modernise after Independence.

Present Concerns

Centuries of foreign occupation by invaders who came through the mountain-passes and by sea have left a deep suspicion among Indians about the vulnerability of the country's borders. A general consensus has grown that freedom and the way of life of independent India can be protected only when its borders are inviolable. This belief has found many proponents including India's first Prime Minister, Jawaharlal Nehru. After the Chinese invasion of India in 1962 he talked of how the mountains which earlier guarded the people from invasion still needed to be guarded. This war and the three wars with Pakistan in 1948, 1965 and 1971 have, if anything, confirmed Indian concerns about the need to protect its borders adequately to discourage further incursions. Analysed objectively, this cannot be the concern only of India, but of many other countries as well, especially when the borders are long, historical and presently disputed. In the 1950s and 1960s many countries tried to defend themselves by entering into military agreements with one or another of the superpowers. Some joined to form strong military alliances and others entered into pacts. India, instead, chose the path of non-alignment. The country believed that military alignment would not only be detrimental to independence as a sovereign nation but would also contribute to increased world tension. Underlying this choice was India's concern about the global growth and spread of nuclear weapons. While many policies of India have changed with the years, this has remained constant under different governments. Though often viewed in the past with suspicion by many countries, the approach is now gaining a slow, but belated recognition from the very countries which once regarded neutralism as immoral.

SELF-RELIANCE IN DEFENCE

A Rationale

The policy of non-alignment has, however, extracted its price. With no military alliance to speak of India has to depend solely on its own defence forces. As arms and ammunition are subject to embargo or political pressure, especially in times of crisis, India had to choose the goal of becoming self-reliant not only in the production of foreign military systems but also in their development. While co-production (regarded in India as licensed production) would have sufficed normally to meet this demand, Indian concerns of its neighbours' military strength had emphasised the need for indigenous research and development so that the systems could always be updated. Pakistan, for instance, was earlier a member of CENTO and was thus a recipient of modern military systems. This continues even today as advanced state-of-the-art systems are still being received from the U.S.. *Harpoons* or *Stinger* missiles are force-multiplier systems for which India today cannot find any suitable equivalent either by import or by indigenous production. This position is not unique in Indo-Pakistan relations. China is another case in point. Immediately after the Chinese Revolution and specially after the Korean War, China set about modernising the military sector, building not only a large nuclear arsenal but also the missile delivery systems. China's achievements in other areas of military hardware have been equally impressive. For instance, nuclear submarines, long-range bombers and armaments have made China not only a major military power, but also an important exporter of military technology. Today China exports sophisticated hardware, such as the *Silkworm* and *CSS2* missiles, to West Asian countries.

India's concerns rest not only with the northern borders, but also with the long length of its coastline. The Indian Ocean today has many nuclear submarines, reconnaissance and monitoring aircraft, not to mention the aircraft carriers that regularly patrol areas which were once zones of peace. There are islands which have been converted into fortresses with deadly weapons and bases in third countries broadened and widened to receive, accommodate and even repair long-range bombers, large naval vessels and other military equipment. Sophisticated electronic surveillance and warning systems proliferate as also do large exercises in once placid waters. India also remembers with concern the presence of a foreign naval fleet, with an aircraft carrier, in the Bay of Bengal during the operation for Bangladesh's independence in 1971.

Research and Development

Indian planning for defence preparedness started soon after Independence. Even though the military build-up was modest in the initial years, plans even then were afoot for creating indigenous research and development capabilities. Jawaharlal Nehru was always impressed by the role of science and technology in building a country's industrial, military and technological strength. He wrote and spoke about it often even before Independence. It was, therefore, not surprising that he asked his friend Professor Blackett, who played an important role as a defence science adviser in Britain during World War II, to advise about the desirability of India creating its own indigenous defence capability. Professor Blackett's report was unequivocal: India must develop her own research and development strength, but restrict it to only those areas which the country's fledgling industry could easily absorb. Thus the development of small arms and ammunition was encouraged and larger areas of research, such as radars, discouraged. Such was the genesis of the Indian Defence Research and Development Organisation (IDRDO).

Initially, the Organisation was mandated to build up the basic research capability required for military hardware, but soon its charter was extended to design and develop indigenous substitutes for imported subsystems, or hard to obtain components. From this base the Organisation grew. In addition to providing designs for components for manufacture, the Organisation also contributed a new word to the English language, 'indigenisation'! There were also designs for small arms and ammunition. For instance, the design of the 7.62mm automatic rifle, the *Ishapore* rifle, can be traced to that period. The IDRDO steadily grew, establishing laboratories in a variety of disciplines, including areronautics, missiles, naval technology and materials.

A Systems Approach to Development

The early 1970s was a period of consolidation of scientific and technological strength. It was also the most difficult period in the life of the Organisation. Investments needed were not then easily forthcoming, but the hopes of the users were already on finished designs and hardware which would normally take long years to produce in developed economies. India's inexperience in developing, proving and manufacturing large systems led both the users and the scientists to underestimate the years of hard and painstaking work ahead of them. There was disenchantment from all sides. The Services felt let down and appeared to lose confidence in the indigenous capability while the scientists were surprised and hurt by their own military's preference for proven foreign systems. The British novelist, V.S. Naipaul, in one of his writings called attention to the Indian craving for foreign products—'anything foreign'.[4] Indian scientists wondered whether this was the case, while underestimating still the enormous research effort involved in developing reliable major systems.

This impasse was overcome by a bold decision of the IDRDO to extend its research capabilities into the development of complete military systems. The arguments for this approach ran as follows: as the developer of sub-systems, IDRDO had very little freedom as it had to meet the proven specifications of a foreign systems manufacturer. This restricted the originality and the design capability of the Indian engineers. Nor did the engineers have the opportunity to design anything new: rather, they were rediscovering the already proven designs which could not by themselves lead to any new hardware. On the other hand, by choosing a totally new system for design and research they became the masters of the entire development. They could, if they desired, even choose proven sub-systems from other vendors to minimise the time and cost of development.

The late 1970s and the early 1980s thus saw the starting of major programs including the development of a main battle tank, light combat aircraft, guided missiles, radar, sonar and other electronic systems, armaments and ammunitions. It must be admitted that the Organisation did not realise the enormity of its expanded program, either in terms of the amount of funding that would be necessary, nor of the country's scientific and technological ability to meet the technical challenges that would be forthcoming.

To date the results of these programs provide interesting observations. The scientific and technological challenges have been well met and have not delayed progress. This may be due to the pooling of the country's scientific and technological talents: universities, industrial laboratories and other institutions were encouraged to collaborate under an active project management team. Bureaucracy and red-tape, the inevitable companions of any program in developing countries, were minimised and accountability increased. Work packages were clearly defined as also were the time-frames and budget. But what was more important was the introduction of peer-reviews in which the performances were thoroughly analysed. For the first time IDRDO introduced systems management in the organisation of a major program.

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4 V.S. Naipaul, *An Area of Darkness*, (A. Deutsch, London, 1964), Chapter 2.

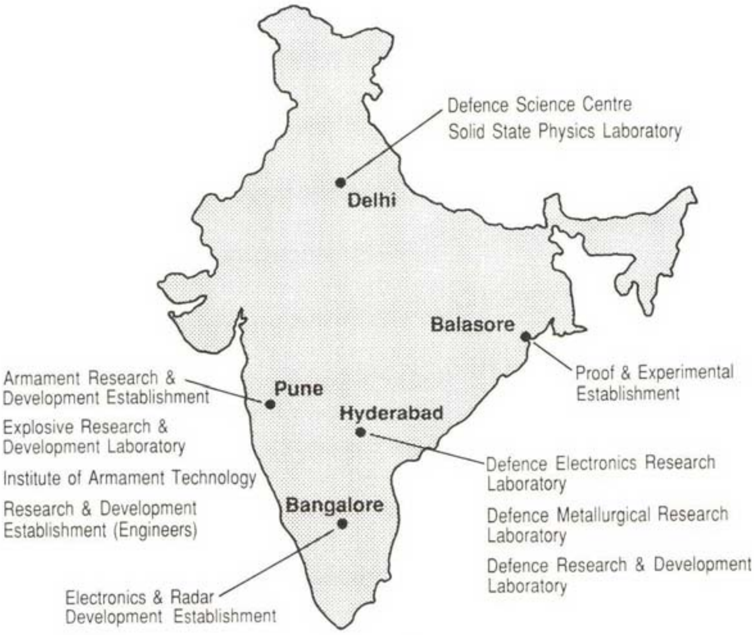
An unexpected but a happy outcome was the performance of production agencies and engineering industries in manufacturing hardware. Many of them had taken up the engineering challenge in spite of their lack of experience in sophisticated technology and stringent quality-control procedures. For the normally conservative Indian industry, the risks of participation would have appeared high and the future profitability low. Notwithstanding, many industries came forward to participate in the mission. Each expected the challenge to rejuvenate their work culture, turning their participation into an important phase in the evolution of industrial sophistication. For instance, an engineering manufacturer made the world's largest rocket motor casing in maraging steel while a metal and alloy manufacturer became the world's largest producer of this sophisticated alloy, which, incidentally, is not readily available in many countries. Figure 5, for instance, shows the number of participating organisations in the Guided Missiles Program in the country.

Taking the leadership in designing major systems also brought about some unexpected advantages. There were gaps in technology in the Indian Light Combat Aircraft Program. India needed the appropriate technology to develop primary composite structures and fly-by-wire systems. Previously the technology had been obtained through international cooperation from countries like France with extensive experience in aeronautics. By clearly and openly stating the objectives, India was able to convey the genuineness of the requirement and able to acquire the technology through normal commercial channels. Similar programs have also brought about an improved understanding from many countries of India's commitment to self-reliance.

Guided Missiles Program and Export Controls

There are also examples in the other direction where self-reliance and self-sufficiency have become mandatory because of export controls and embargoes unilaterally imposed by some countries. India is convinced that missiles provide an optimum option as weapons and their improved accuracy over long-ranges make even nuclear warheads unnecessary. Indian missile development had therefore taken into account the non-availability of components and systems from other countries. The program was largely indigenous, providing greater challenge to the technological community. Though it was initially feared that this road would be long and arduous, the present experience is happily different!

FIGURE 5
PARTICIPATING ORGANISATIONS IN THE INDIAN GUIDED MISSILES PROGRAM



19	DRDO Laboratories
7	Academic Institution
7	Other Organisations
21	Public Sector Undertakings
6	Private Sector

The existing scientific and industrial infrastructure has met the challenge and solved many technical problems, making imports of critical components and technologies under imposed guarantees largely unnecessary. For instance, the recent test firing of the *Agni* missile confirmed Indian capability to design and develop complex systems such as accurate guidance and control systems for long duration operations and also the re-entry structures capable of withstanding very high temperature loads. Many new technologies, though admittedly less dramatic, have also been developed by this route, leading to the creation of a strong and sophisticated electronics base.

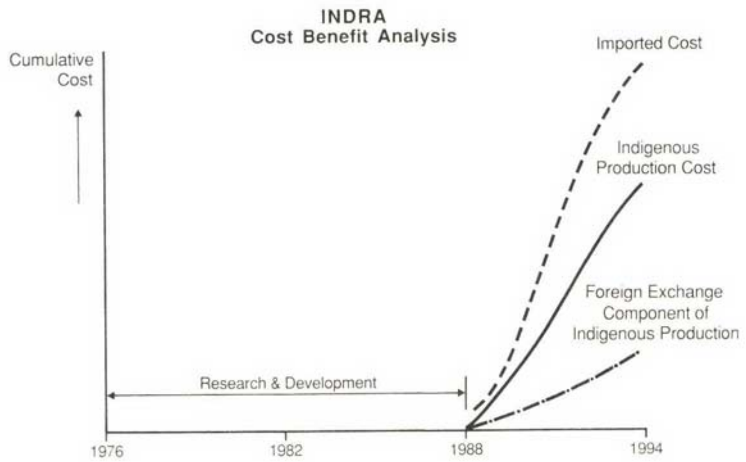
India opposes the principle of embargo and denial of technologies. In the Indian view such denial smacks of past colonialism when countries, by themselves, made decisions affecting the colonies they occupied and ruled. But India is also conscious that denial of technology is an old game played by many countries through centuries. During the industrial revolution the British prohibited the export of Newcomen engines to the U.S., and Sardinia prohibited the export of silk-combing machines to England in the eighteenth century! The experience of Great Britain and France in acquiring nuclear technologies from the U.S. immediately after World War II was also one of disappointment. Both countries had to develop their own technological capability as nuclear-weapons powers before they were able to receive overt and covert assistance from the U.S.. If these experiences are any indication, countries appear to respect others only when their technological base is parallel. There is also a responsibility that goes with the development of technology. It is to ensure that sensitive technologies do not fall into the hands of terrorists, military juntas or dictatorships. India is vitally concerned about being a victim of the proliferation of sophisticated arms within the South Asian neighbourhood. The very availability of sophisticated missiles in the black-market has helped terrorists and even some small countries to equip themselves with such force-multiplier systems that destabilise the already troubled regions of Asia. The Indian track-record in guarding sensitive technologies is exemplary. No sensitive nuclear technology has been transferred to countries seeking them for non-peaceful applications even though attractive economic incentives were proferred during the oil crisis.

TRANSLATION TO PRODUCTION

Where will this lead India's defence preparedness? India has already set up production centres and factories to manufacture tanks, aircraft, submarines, and electronics systems. Though these were originally commissioned to manufacture hardware under licensed production, they have also formed an adequate base to manufacture indigenous systems now under development. The economics of manufacturing such systems are so attractive that it is proving to be even more viable than importation under favourable terms. Figure 6 illustrates how the local development of radar systems affects the economy. Indigenous production will be even more attractive with high-volume production. Unfortunately, this economy of scale is not yet available in India.

Many arms-exporting countries generally amortise their research and development expenditure by encouraging the export of local production. India is now seriously considering this choice. There are other options. By cooperating during the research and development phase with other countries it is possible not only to reduce the time-frame but also the cost of development. Often upgrading ageing equipment can provide new sub-systems for major programs of the future at lower cost.

FIGURE 6
INDRA[5]—COST BENEFIT ANALYSIS



5 *Indra I* and *Indra 11* are low level (air) detection radars developed by The Electronics and Radar Development Establishment, Bangladore (part of DRDO).

India is also discovering that many military technologies also have a civilian application. A good radar with a network can be modified to become a useful air traffic control system for civil aviation. But such developments will only become reality when industry has the flexibility to transfer technologies and products across sectors. This is not as easy as it sounds. Many countries in the past had separated defence production from the rest of the manufacturing sector to ensure security and also to exercise stringent quality-control irrespective of the costs involved. This has now become a liability. For instance, in the Soviet Union the quality and performance of defence manufacturing units has not spread to other consumer industries. On the other hand, defence industries are often blissfully unaware of the costs involved. The Soviet Union thus finds itself in the unenviable position of having to encourage production sharing and performance control within both the defence and civilian sectors. The Chinese experience also appears to be similar. To an extent India is better qualified to encourage such diffusion. Its factories have had inputs from many Western manufacturers who paid some attention to the costs involved. Another redeeming aspect is that very few factories in India produce solely for the defence sector. Many produce largely for the civilian sector. For instance, a leading electronics manufacturer of defence equipment also produces radio and television station equipment and telecommunication systems. The coming years will show how efficiently India has been in linking the two categories. Success will be possible only when the civilian sector itself appreciates the importance of self-sufficiency in its basic materials. As there are no embargoes and easy-credit terms are available there is a strong temptation to import or locally-assemble imported components. This strategy would be in order for countries without a significant industrial base or a strong commitment towards self-reliance in its defence needs. For India, however, options in civilian technologies need to be exercised on the basis of established capacity for manufacture and the availability of appropriate technology. Only by such a planned approach is it possible to fully utilise the production capacity established for defence, and make the manufacturing centres flexible enough to change between defence and civilian requirements. It would indeed be a pity if India manufactured the more stringent military communication systems, but imported the civilian communication systems from foreign vendors!

CONCLUDING REMARKS

The Indian quest to become self-reliant in defence systems and the determination to guard its borders is unfortunately misinterpreted as a craving to be a regional power and a desire to engage in the projection of emerging military strength in the region. A self-reliant and strong India is not only good for the stability of Asia, but for the entire free world. India, with a large population and thriving secular and democratic institutions, provides an attractive example for many of the developing nations still choosing among the various options available which may even include military dictatorship and religious fundamentalism. India, in turn, is finding the road to self-reliance often mistaken by neighbours. The acquisition of one nuclear submarine solely for training is taken as a potential threat to the sea-lanes in the region. A single test firing of the *Agni* is perceived to have made India a missile power, yet there are many countries in the region who have acquired the very same capability either through military pacts or even by purchase.

Some of these criticisms may well be inspired to discourage this non-aligned nation becoming militarily strong and this may validate the Indian philosophy of non-alignment—a still unacceptable proposition in some quarters. Arguments are usually aired that India, a poor and economically-backward country, has so many pressing economic priorities that the country can ill-afford to spend money on defence, overlooking the obvious fact that the country requires a secure environment so as to prosper. The other argument is that India would become belligerent and a regional bully. The regions surrounding India are not very peaceful even today. The concept of the Indian Ocean as a zone of peace is not widely accepted. There are nuclear submarines in the region and missiles with nuclear warheads standing in readiness. But these are accepted and perhaps condoned as the only way to maintain peace and stability. Viewed in this context, the building-up of Indian defence does not introduce instability—if anything, it provides a secure environment not only for India but to many other small countries, who much against their will are tossed between offers of military pacts and alliances. Over the years, India has accepted these criticisms philosophically as it realises the only other choice would be to remain weak and forever dependent on others. If this were to happen, it would be a tragedy of epic proportions. This choice ignores cherished principles and the strength and determination of the Indian people to be in control of their own destiny.

PART II

TECHNOLOGY AND THE DEFENCE OF AUSTRALIA

CHAPTER 6

AUSTRALIAN DEFENCE POLICY, TECHNOLOGY AND INDUSTRY

Kim C. Beazley

One of the features of the current defence debate in this country is the way in which some of the Government's critics now cite the welcome changes in U.S.-Soviet relations in attacking our adoption of a self-reliant defence policy.

The notion that a lessening of superpower tensions should immediately impact on Australian defence planning has a certain irony for a Labor defence minister. One of our chief concerns for many years has been to focus our defence strategy squarely on our own region, rather than on the military capabilities of the Soviet Union.

After five years in the defence portfolio it seems the wheel has come full circle. When I started out in defence one of the difficult tasks I had was to convince people, particularly our critics on the right, that our defence planning should be centred on the defence of Australia rather than the perceived threat from the Soviet Union. The irony is that it is now some of my critics on the left who contend that we should adjust our defence posture in keeping with a more benign view of the Soviet Union.

We welcome the new understandings now being reached between the superpowers. For the first time in four decades we can take heart that the threat of global destruction has diminished. To this end the role of the Joint U.S.-Australia Facilities in contributing to the improving U.S.-Soviet relationship has played not an insignificant part.

However, the current extraordinary pace of change in Eastern Europe and the Soviet Union will have little direct impact on developments in our own region. The changing global balance of power, and the trend towards multi-polarity, in both economic and military terms, will accelerate if the warming in U.S.-Soviet relations continues.

The complexity of the changes now under way in our region pose significant challenges for the development of strategic policy.

Looking at strategic developments in the Asia-Pacific region, one begins to see something which looks like more like a political map of 19th century Europe, with its shifting alliances, than the more or less bi-polar world which has endured since World War II. Our region is rapidly becoming one of changing alignments and arrangements involving an array of large and medium powers.

In the context of our own self-reliant defence posture new technology has a fundamental role to play. We require the innovative use of technology to sustain a credible defence policy.

That we can confidently assert the fundamental concept of self-reliance and have confidence in our ability to defend Australia is due in no small part to the development and use of technology in key areas.

With our small population and enormous northern coastline, effective defence must necessarily be reliant on some high technology systems. This imposes major challenges for our scientific community and industry. This is because many of our defence technology problems require uniquely Australian solutions. We cannot buy all we need off the shelf from overseas.

We have requirements for surveillance and sensor systems which do not necessarily impinge on developments in the northern hemisphere. Our defensive systems have to be able to cope with the extensive areas of shallow waters around our coast, the warmer temperatures of our northern seas, hot-dry and hot-wet climates, vulnerability of communications, distances and harsh conditions imposed on land transport.

Resource constraints pose especially formidable challenges for Australia. With a population of only 16 million, there are necessarily severe constraints on the level of investment and manpower that can be devoted to the defence of Australia. In 1989/1990 we will spend an estimated 2.3 per cent of GDP on defence. It will be the lowest share of GDP allocated to defence since 1950.

Our strategic environment has, from a military viewpoint, two contrasting faces. Our geographic isolation, extensive maritime approaches, harsh northern climate and the location of major population and industry centres in the south east all provide substantial protection against the prospect of major attack.

At the same time, the size of the continent and the dispersed location of potential targets in the north and adjacent maritime areas make Australia vulnerable to more limited forms of military pressure. Our ability to respond is not helped by our small population in relation to the area of operation, nor by the lack of supporting infrastructure in central and northern Australia.

Our strategy of defence-in-depth is designed to ensure that our defence force has the capability to maximise the difficulties for an adversary while minimising our own. This requires the ability to meet hostile forces in our maritime approaches wherever possible, and to conduct timely and efficient operations across the breadth of northern Australia.

The effectiveness of our strategy hinges on several vital operational requirements. These include effective surveillance over Australia's northern approaches; the development of highly mobile forces with the ability to respond quickly over extended distances; the capacity for sustained operations in the north in areas remote from major bases and supporting infrastructure; and the integration of air, naval and land operations to ensure a timely response.

Each of these operational requirements demands the selective use of technology. In some cases the solutions we need are yet to be developed and we will have to exploit our own Australian technology to achieve this. Our policy of self-reliance does not mean complete self-sufficiency for our technology requirements but a careful balance of indigenous and imported solutions.

We must be able to enhance our own capabilities for technological support, modification and development, particularly of systems designed to meet our unique requirements.

Here the role of our Defence Science and Technology Organisation (DSTO) has been invaluable. DSTO provides specialist scientific expertise to provide advice on technology options, the adaptation and modification of systems and the development of indigenous equipment. DSTO's fine work in developing systems such as the laser airborne depth sounder and the *Kariwara* towed array as well as our *Jindalee* over-the-horizon radar (OTHR) have been of vital importance to our defence effort.

OTHR is perhaps the best example of the very substantial contribution that Australian technology and industry has already made to the development of defence self-reliance and the implementation of our defence strategy.

We have a fundamental requirement to conduct surveillance of our vast sea and air approaches. We need to be able to detect, identify, and, if necessary, respond to sea and air activity in our sovereign air and sea space. Ground-based or ship-based microwave radars lack coverage beyond about 250 nautical miles for high flying aircraft. For the detection of low flying aircraft and surface ships the range is more limited.

DSTO conducted research and trails for a decade on using reflections from the ionosphere and developed the basic hardware and software elements for an experimental over-the-horizon radar system. In 1987 the Government authorised the first stage in the establishment of an operational system. We now have three Australian companies - AWA, BHP, and Telecom - competing for the prime contract for the operational radar network which is expected to be awarded early in 1990. The Australian content in *Jindalee* is expected to be in the order of 70 per cent.

The Government's 1987 Defence White Paper said: 'Without an OTHR network we would remain essentially unaware of movements of interest in our vast maritime approaches'.[1]

More than any other factor, the development of OTHR has made the defence of Australia against credible threats viable and defence-in-depth practical. As I have pointed out on many occasions, this quantum leap in radar technology will make, indeed is already making, our physical surrounds 'transparent'. It makes a strategy based on defence of the sea/air gap achievable.

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1 Kim C. Beazley, Minister for Defence, *The Defence of Australia 1987*, (A White Paper presented to Parliament in March 1987, Australian Government Publishing Service, Canberra, 1987), p.35.

To understand the special role of technology and research and development in Australian defence planning it is important to appreciate the factors that drive our application of technology.

Some forty years ago, our strategic planners were firmly of the opinion that the basic tenet of our defence posture must be imperial cooperation. Australia's size was judged to demand armed forces and an industrial potential quite beyond its capacity.

Strategic dependency carried an assumption that our defence force would not be called upon to defend Australia's territory and immediate approaches. The rationale of a dependent strategic posture was to ensure that if the Australian Defence Force (ADF) has to fight, it would do so in support of allies as far from Australia as possible. If Australia itself needed to be defended, the fighting would primarily be done by our allies' forces rather than our own.

Our old dependent posture precluded any thought that the capabilities of the ADF should be developed in a systematic way to meet the particular strategic challenge of actually defending Australia itself.

The concerns of those earlier defence planners were not, however, without some foundation. Our population was small; the northern coastline was extremely long; memories were all too recent of the Pacific war in which the numerical size of forces was often critical; and the fear was either of a communist invasion or a resurgence of Japanese imperialism. What was not appreciated were the unique strengths and vulnerabilities of Australia's strategic environment.

The challenge for Australia is to develop appropriate technological solutions for the defence of Australia. They must be affordable and matched to our needs. I am on record as stating that OTHR needs a complimentary airborne early warning and control system (AWACS). We cannot afford and do not need the very expensive U.S. AWACS designed for the European theatre. We await a considerably cheaper and, hopefully, simpler solution.

There are some innovations that we have fostered which, while not essential for our defence, nevertheless give us the opportunity to maintain our technology base and collaborate with allies. The anti-ship missile system known as *Mulka* is a joint project with the U.S. Navy. It is the first major collaborative equipment project with the U.S.. At this stage full scale engineering of the system is proceeding. DSTO at Salisbury is leading the development of the propulsion unit and Australian Defence Industries (ADI) is developing the canister and motor hardware and the launcher.

I would like to discuss briefly some of the structural decisions we have had to take to achieve a credible self-reliant defence posture. We need to remember that the technology we employ for defence self-reliance, if it is to be sustained and enhanced, must evolve from a competitive and efficient industry base.

Five years ago we set out quite deliberately to reshape our local defence industry and overhaul the industries vital to our defence. These embraced electronics, aerospace, shipbuilding and ship repair, heavy and general engineering and munitions.

These industries are not just essential elements of the industrial base needed to achieve self-reliance. They are equally essential for the type of industry structure our government has sought to encourage to serve Australia into the next century. The aim has been to develop a structure that is global in outlook, export oriented, and internationally competitive.

Preceding this program of industry restructuring the Government has already taken a number of important macro-economic decisions. We floated the dollar and deregulated the financial system, which facilitated the overhaul of key industries. Restructuring industry and reforming fiscal and monetary policy has enhanced Australia's competitive position in the world.

In the case of our government-owned defence factories we reduced the number of employees in dedicated defence manufacturing facilities from more than 15,000 to 6,800. In May 1989, we formally launched ADI, a new company which has taken over the management of the eleven major defence industry facilities still in government hands.

As well as closing two factories we sold the Williamstown Naval Dockyard in Victoria and converted the former Government Aircraft Factories into a government-owned enterprise, Aerospace Technologies of Australia (ASTA).

A key objective has been to foster Australian prime contractors with the technical, managerial, and financial strengths to undertake large defence projects. Such firms will be able to ensure not only technology transfer and high levels of local content, but also have a better chance in export markets.

Our decision to build submarines and frigates in Australia, rather than buy off the shelf overseas, prompted a major restructuring of the Australian shipbuilding and ship repair industries.

Without that rationalisation and overhaul of our dockyards we could not have contemplated a $9 billion dollar program embracing six submarines and eight frigates. The privatisation of the Williamstown Naval Dockyard resulted in employment in the yard being reduced from 2,200 to 750. Twenty-three unions were reduced to three and productivity on site has increased at least four-fold.

The submarine project has given Australian industry the opportunity to invest in an enormous range of state-of-the-art technologies. It is worth recalling that 70 per cent of the platform work and 45 per cent of the combat system work is to be done by Australian industry. The value of this work is around $1,800 million.

Already sub-contracts have been placed with Australian industry to a value of $850 million. A total of 35 Australian and 31 overseas companies are currently involved. The technology transfer to Australian industry includes skills in micro-alloy steel development, optics-electronics testing techniques and precision fabrication. Flowing directly from the submarine project is the opportunity for developing our own centres of excellence in areas such as software development, battery technology, and management information systems.

The ANZAC frigate project will accelerate the transformation of Australia's marine engineering sector and further consolidate growth in the high technology areas, such as systems engineering, that have developed from the submarine project. Australian and New Zealand content in the frigate project could reach 80 per cent. The cost premium for building the ships in Australia has been estimated at around four per cent—a dramatic reduction in the premium level we might have anticipated a few years ago.

Underlying this drive to overhaul our defence industrial base is the assumption that we will develop a capacity to export. The promotion of defence exports to a range of suitable countries is merely a modest aspect of our overall exports drive but based on the same imperatives. Australian industry must be export competitive if it is to survive and prosper.

In some areas Australia has been able to develop particular technologies which have gained a competitive edge in international markets or a strategic advantage in the defence arena. One such area is radio propagation studies. Australia's vast distances and the peculiar problems of HF and VHF propagation in the tropics has established a tradition of ionospheric and tropospheric research dating back to World War II.

One result of this research has been the development of OTHR. Another has been the overseas sales of single station location stations for HF radio direction finding, together with advanced software packages to aid calculations in the prediction process.

Another example of Australian leadership in the software area is in cryptography. Overseas sales of cryptographic equipment, primarily for banking and financial purposes, are expanding.

The Materials Research Laboratory (MRL) has been a world leader in explosives technology. In collaboration with the U.S., the MRL is continuing a fruitful line research into high explosives simulation.

It is important to remember that defence self-reliance does not isolate Australia, either strategically, industrially, or technologically, from its friends and allies. We cannot hope to meet all our technology requirements for the defence of Australia alone.

Here the practical benefits of our alliance with the United States has helped underpin our shift towards a more self-reliant defence posture. The prospect of substantial U.S. assistance remains, of course, a significant consideration for any country contemplating a major attack against Australia. The real benefits of the alliance are, however, 'here and now' links between our own intelligence collection capabilities and those of the U.S., which provide assurance that we can detect any adverse developments, political or military, likely to affect Australia's security or that of the region. This allows us to regulate our planning and to have confidence that we can react in a timely fashion to any deterioration in our strategic circumstances.

The alliance gives us access to high technology equipment we cannot afford to develop ourselves as well as the skills and information which are necessary to maintain and operate them, and to adapt them to our unique strategic environment. The exchange of expertise is a vital element in our ability to develop the technological base relevant to self-reliance.

As a member of the Western alliance we enjoy access to a range of sophisticated technology, which has been recently enhanced by our membership of COCOM.

At this point it is worth considering the impact of new technology on our regional relationships. We have adopted a defensive military strategy and the appropriate technology systems are essentially defensive in nature. Our defence policy and capabilities remain firmly focussed on the self-reliant defence of Australia and its direct interests.

At the same time, we would be extremely short-sighted if we saw our security interest stopping at the point of possessing a defence capability against some ill-defined possibility of hostilities in the short or longer term. We need to contribute to the maintenance or a stable regional environment and to foster common security perceptions with neighbouring countries.

Those benefits do not come from countries like Australia sitting back and mouthing appropriate sentiments. They demand practical and sensible cooperation in a range of areas, not least of which is regular and mutually beneficial interaction with the defence forces of neighbouring countries.

Part of the process of improving our own technological capabilities is a continuing dialogue with friends and neighbours. As their own self-reliant defence capabilities are steadily enhanced, sometimes with Australian help, the value of joint exercises with neighbouring forces is increased. We commend ourselves by our willingness to take their defence requirements seriously.

It is important to consider just what it is we are trying to achieve and why it is appropriate, and to an extent necessary, that Australia plays such a role. There are three key elements:

- First, the stability and strategic cohesion of the region contributes directly to our own security. Strategic planning has acknowledged for many years that any significant hostilities against Australia would need to develop through the maritime approaches to our north. Our security is closely tied in with that of the ASEAN states in particular.
- Second, Australia is a substantial power in military terms within our region. We should not shy away from this, but we do need to accept that it creates certain expectations of us—particularly when responses to shred security concerns are under consideration. Our ability to influence our environment depends on what we are prepared to put in.
- Third, we need to recognise that the highest priority, maintaining military capabilities for the defence of Australia, is very costly and demanding. The more constructively we can contribute to a favourable strategic environment, the more manageable our own defence requirements become, particularly in resource terms.

These points are not a prescription for Australia taking a major military role well forward of our shores. That is beyond available resources and would be contrary to the priority we attach to defence self-reliance. What they do highlight is the need for Australia to be prepared to contribute constructively within the region.

Some of our critics are now questioning why this activity is necessary. Peace is seen as breaking out. The superpowers are reducing their arsenals of nuclear weapons. The strategic map of Europe is being redrawn.

The developments in other parts of the world tend to overlook what is going on in our own region. It is not a question of any immediate or direct threat emerging, but a series of more complex developments which have the potential to place pressure on the broad strategic consensus which presently characterises the region.

Australia remains one of the most secure countries in the world. No neighbouring country harbours aggressive designs on Australia, and no country has embarked on the development of the kinds of capabilities that would be necessary to militarily threaten Australia.

In our defence planning we address the simple facts of geography in the light of what history tells us about the vulnerability of our northern approaches. No contemporary political changes threaten us, but we know from historical experience that we are capable of being threatened.

This divorce of geography from contemporary political trends highlights the time scales on which defence planning is done. For example, our F-111 aircraft were ordered in 1964; they were delivered seven years later; they will remain in service at least another ten years and the Air Force hopes another twenty. If the Air Force is right it will have been forty five years between the decision to buy them and their retirement.

Consider a more recent example. In October 1989 the Government decided to build eight new ANZAC frigates. The first of them will be delivered in about five years, and the last one will be delivered about ten years after that. Each ship will stay in the fleet for around thirty years. So, again, forty five years from now the ADF will depend on capabilities developed by government today.

Against this sort of time-scale, political projections become pretty irrelevant. For example, forty five years ago Southeast Asian countries had only just begun their long struggle for independence and national unity. When you are planning on such time scales, you have no alternative but to focus on the enduring features of geography. They are the only things you can be sure will still be around when new capabilities come into service, let alone when they are retired.

So the divorce of strategic geography from contemporary political reality is not just a dramatic device to avoid embarrassing our neighbours. It is an unavoidable reality of defence planning.

Over the long term the prospects for strategic stability in the Asia-Pacific region are by no means certain. Economically the region is forecast to expand more rapidly than any other part of the world. The newly industrialising economies of Asia, Korea, Taiwan, Thailand, Singapore, and Hong Kong are currently growing at rates of around eight per cent per annum.

The nations of Asia are expanding their military capabilities. As they grow richer, they are spending more on defence, and their defence forces are becoming more technologically advanced. In particular, as they exercise their national sovereignty, they are putting more relative weight on high technology maritime forces than on low technology land forces. So their force projection capabilities are gradually increasing. This is happening already in India, China, and the ASEAN states, and within a decade it may well be happening in Japan.

New military technologies are being developed as industrial capability grows. Already a number of countries are developing ballistic missile and chemical weapons capabilities. In this regard the U.S. alliance and the Joint Facilities which we host have a renewed importance, helping us monitor developments which may be inimical to the interests of our regional friends and allies. These developments heighten the need to promote the sense of shared strategic interests which is the cornerstone of our defence relations with Southeast Asia. This includes technology exchanges and collaboration on defence projects which can positively contribute to regional security.

The strategic changes in the Asia-Pacific region will continue to pose significant challenges for the development of our own strategic policy. In developing a defensive self-reliant defence posture we seek a constructive approach to cooperation with our neighbours. Far from threatening, intimidating or overwhelming them, our defence strategy allows us to shape our future in concert with our neighbours. New technologies impact in the same way on Australia as they do on other nations in the Asia-Pacific region. Prudence suggests we should all pursue defence postures which are fundamentally defensive.

CHAPTER 7
TECHNOLOGY, STRATEGY AND THE DEFENCE OF AUSTRALIA

John Baker

The use of technology is not included in the Australian doctrine setting out the principles of war and nor should it be. Those principles deal primarily with the most effective application of available force, rather than the longer term considerations of national strategy and force development. But the conduct of armed conflict is increasingly influenced by technological developments, which allow military tasks to be conducted more efficiently or effectively.

The impact of technology is not a question primarily for the field commander. The battlefield or operational task is to use suitable assets to best effect and to create dispositions and develop tactics which minimise as far as practicable any technological advantage enjoyed by the enemy. But increasingly technology issues will have relevance for strategic and policy planners shaping the force structures, capabilities and support for the field commander.

Technology has an impact not only on tactical techniques and military doctrine but also on future forms, intensity and scale of conflict. Therefore it has a direct relevance to the strategic planner not only in military terms but also in terms of the national capacity to provide, support and sustain the military capabilities.

The long-term planner faces a formidable problem. Much of the technology available to the field commander today was conceived ten or more years ago. We are making decisions now about the structure of our force in the year 2000 and beyond. Thus, strategy is concerned not only with the future; it must also buttress those choices which must be made today. Usually they will be hard decisions, often made in periods of intense competition for resources and not helped by ever-expanding technological horizons and uncertainties on costs.

Thus there are a number of fundamental questions to be addressed. These include:

- Will technology drive strategy and force structure development or can it be harnessed?
- How will conflict change?
- What commonality exists between defence and other national requirements?
- To what extent can and should the strategy rest on technology?

Of course there is nothing new in these questions. They have been asked before and perhaps there are no universal answers. Nevertheless they deserve examination because the very act of review might provide some useful guidance for strategic and policy planners. This will be done in an Australian context, a special, if not unique, set of circumstances, but some of the broad considerations may be relevant also to others.

THE ENVIRONMENT

Any consideration of Australian strategy must be placed in a global context. At present, given the significance and pace of change in superpower and major-power relationships, this is not of itself simple. We may well be witnessing a major turning point in the system of power relationships in central Europe, with consequences that cannot yet be assessed. And change has probably now gone so far that even if Gorbachev and other reformers lose the political battle, the Soviet Union and the other countries of Eastern Europe could not return to the discredited economic and social systems that have symbolised the communist states in the post-World War II era.

Of course there is not much that regional powers such as Australia can do to influence such developments. But there is a fundamental lesson in the Soviet experience. It is not only that the Soviet-style of government and central planning was inefficient, but that the Soviets adopted a strategy which was pursued at the expense of other sections of the economy. Although complex, it is interesting to speculate on the degree to which grandiose defence policy objectives made fundamental social change in the USSR inevitable, even without Gorbachev. But it was clear that technologically and industrially the

Soviets could no longer hope to match the West and, at the same time, preserve massive forces. Ultimately for all nations the defence objectives need to be affordable and sustainable in social, financial, technological and industry capability.

Expectations of better relations between the superpowers are generating perceptions of a decrease in global arms expenditures. But this situation is dominated by a relatively few larger nations. In a number of regions, including our own, defence expenditures continue to rise. Nevertheless, the decrease in global tensions will provide special interest groups intent on reducing defence expenditures and capabilities with leverage to exert pressure on defence policy and programs. New Zealand has experienced this, and there are signs in Australia of the growth of as yet small groups prepared to debate the level of defence spending.

In this context, there has indeed been a remarkable change in media reporting in Australia. It is only recently that the government was being criticised for neglecting defence and allowing the Australian Defence Force to wither. More recently, despite little real growth in defence spending—and in fact a decline in the percentage of GDP applied to the defence sector—the criticism tends to be the reverse. Although neither of these positions is necessarily well-researched or balanced, both demonstrate the need for careful handling, explanation and wide understanding of policy directions. Strategic planners, through media reporting of conflicts such as Vietnam, have come to recognise the effects of public opinion on the conduct of operations. Now too the same effects might be felt increasingly on policy, particularly where defence technology and industry requirements differ substantially from those associated with commercial needs.

The U.S. will not be exempt from such considerations. Congressional pressures, already experienced over some significant programs, may become more widespread and there may well be increased calls for greater burden-sharing. Nations with defence arrangements with the superpowers may therefore face pressures for increased defence spending, at a time when the population at large is optimistic about prospects for peace.

A further consideration is the ready availability of advanced weapons systems on world markets. Both commercial interests and some governments are engaged in aggressive arms-marketing campaigns, often at attractive prices. And with growing prospects for conventional force reductions in Europe, together with Chinese and Soviet needs for hard currency, competition for market share is likely to persist for some time.

But this ready availability of systems brings with it new strategic problems: those of the absorption of technology and issues of self-reliance. It is one thing to possess modern systems, it is another to make the most effective use of them. For example, smart weapons require not only the operating systems but also target-acquisition systems, electronic warfare capabilities to overcome countermeasures, and command and control arrangements, all adding to the complexity of the battlefield. These complexities can be overcome by effective training, often including simulation to overcome high costs. But training is also made easier in a society which has educational programs to provide an advanced recruiting base.

Even if the military organisation and training challenges are overcome, there remain issues of maintenance and modification of systems purchased overseas. Although it is practicable to negotiate overseas maintenance contracts as part of the purchase package, these generally involve cost and pipeline penalties. Nor do they remove the requirement for systems proving and lower level maintenance, which must be done locally. Further, systems developed primarily for European conditions will frequently require local modification to suit best the regional operating environment. Importantly, higher technology, more capable systems are also likely to be more costly to acquire, and thus are likely to be available in smaller numbers. This makes ready availability of key systems desirable, if not essential. Therefore, it should not be assumed that overseas procurements and support eliminate the need for domestic industry and technological support.

National technology and industry policy will become of increasing importance to the strategic planner. And this will be complicated by growing problems in intellectual property and technology transfer issues already being experienced and having the potential to worsen. It cannot be assumed that the commercial and security policies of major arms suppliers will always coincide, particularly if significant conventional force reductions and budgetary pressures grow. But these difficulties serve to slow rather than prevent the inevitable spread of technology. They assume greatest importance in times of crisis when military commitments are imminent and delays in achieving optimum operational performance are at best undesirable. Thus the availability of technological and industry support will become of increasing relevance in facing force structure decisions.

Alternatively, planners need to look for new forms of international defence arrangements or treaties. The traditional form of agreements to consult or to provide direct military contributions may need to be supplemented by undertakings for the ready exchange of technical data and industry support. But even then there is a need to recognise the limitations of such arrangements, which will be subject to change according to the policy variations of either partner when views of strategic priorities diverge.

Technological and industrial self-sufficiency is an impracticable objective for all but the superpowers. But equally, total dependence is undesirable for both operational and policy independence reasons. Thus, a critical strategic decision is the shape and dimension of the defence scientific base and its relationship to national industrial developments. Further, given the lead times involved in each of these aspects, the strategic decision is not one which can be related only to short-term assessments. A long-term view based on enduring features of the national strategic environment is desirable.

Most nations prepared to devote the effort and resources to long-term programs can acquire a range of modern military technology. The limitations are the total cost and human skill base, both of which affect the length of programs rather than the practicality of technology transfer. But international concern about proliferation of certain weapon classes has again become evident. Much of the work of the superpowers concerning control of strategic forces would be undermined by proliferation of nuclear weapons, and international attention is being given to chemical weapons. Australia's interests are served by the international efforts to strengthen the nuclear non-proliferation regime, and to establish an effective regime to ban chemical weapons.

THE CHANGING NATURE OF CONVENTIONAL CONFLICT

The inexorable acceleration in technological development raises the inevitable question for the strategic planner of how technology affects the nature of conflict. But the question applies not only to the future battlefield. It is relevant also to the organisation for war.

Over the years there have been many claims, often by proponents of particular weapons systems or by elements of military forces with a parochial view, that there would be rapid and significant change. The anti-tank guided missile was hailed by some as the end of the tank; the survivability of major surface ships is perhaps a contemporary debate. But these arguments tend to neglect both tactical and technological advances. Just as technology produces new systems, it also provides countermeasures, although often with a time-lag.

There has been significant change from the static trench warfare of World War I, through *blitzkrieg* to recent concepts for the conventional defence of Western Europe. But despite the modern weapons systems used, the recent Iran/Iraq conflict had many of the characteristics of the trenches and chemical attacks of the World War I. Then there are also the insurgency campaigns post-World War II, highlighted by the success of the North over the South in Vietnam. So perhaps it is not technology alone that will affect the nature of conflict, but rather the combination of innovative military thought exploiting whatever technology is available, or driving technology in particular directions.

In future conflict, a key element will be the ability to influence the nature of the battlefield, not only technologically but also psychologically. It is difficult to win through technology if the crux of the conflict is hearts and minds. This is not to say that technology is not important in seeking tactical advantage on the battlefield. It will always be important to provide armed forces with the best prospect of success with least casualties. But perhaps more importantly from a strategic viewpoint, we should look to technology to control the nature of the conflict itself.

This is particularly relevant to island or archipelagic nations, such as Australia which has no land borders. The amphibious invasion, perhaps the most difficult and complex military operation of all, may in future be impracticable against a well-prepared defender with high technology weapons systems. It is not that such operations will be totally impossible, but rather that the cost will be so high, and the forces required so large and well-prepared, that invasion would be rarely worth the effort or cost.

A key technological development to bring about this situation is the availability of surveillance, and particularly overhead systems. No longer is it practicable to hide the extensive preparations needed for major military undertakings, particularly where these involve the assembly of forces for crossing a substantial water gap. Coupled with this is the ability to track and report in real time the actual deployments of such forces. Further, it is difficult to see any effective countermeasures being available. Although small elements of the force might be concealed, the total extent of preparation will remain obvious. Even a measure of surprise as to the timing and direction of the primary assault will be difficult to achieve.

For the defender, it is one thing to know about the preparation by a potential aggressor; the other requirement is to have a counter. This lies in air power, the combination of range, speed of reaction and stand-off capability which makes defence of an invasion force at sea so difficult unless the invader can achieve substantial and sustained air superiority throughout the passage, landing, consolidation and sustenance of the force. Over an extended water gap, it is difficult to see how such superiority could be achieved without the addition of substantial and sophisticated sea-borne air capability. Even then, land-based anti-shipping missiles could pose a considerable problem as the force approached the lodgement area.

Thus for an island nation prepared in peace to invest in its own security, technology offers a reasonable prospect of security from invasion. It is practicable to control the substantial conventional threat environment, given the political will to so do.

Yet there remains the prospect of lesser threats—the use of military force not for military domination of another nation but for coercion. Here the military problem is different. It is not a matter of national survival, or of holding ground, or of destruction of the opponent's ability to wage war, but rather one of achieving a cost-effective solution. That is, a solution in which a nation prefers, for both economic and psychological reasons, to provide a military counter rather than political concession.

There are a number of characteristics of such conflicts. In the first place, they will generally be regional, usually associated with border, resource or economic issues sufficient to justify the use of force. Often they will be between neighbours, disputes which should not arise if enough effort had been put into building sound relationships between nations on a basis of mutual respect and cooperation. But human nature and nationalism being what they are, such disputes always remain possible because emotion will often rule logic.

Low-level conflict will usually be preceded by a political dispute, but because there is only limited preparation needed, there may be little military warning of the actual use of force. Invariably they will involve political or diplomatic resolution to achieve a settlement. Often they will be extended disputes because neither side will be seeking complete domination or destruction of opposing forces. But without effective crisis management, they could easily escalate to more substantial and costly conflict. But such escalation is likely to be limited by national military, economic, industrial and technological capabilities, because the nature of the dispute may be such as to involve little sympathy, let alone direct support, from distant friends or allies.

Of itself, high military technology will not prevent low level conflict. Concepts of deterrence are irrelevant. The best security lies in establishing relationships which avoid the temptation to resort to the use of force. But in the absence of such mutual confidence between nations, technology has important applications in controlling escalation and in keeping the cost of defensive measures within acceptable limits.

AUSTRALIAN STRATEGIC PLANNING

In the absence of identifiable military threat, objectives set now will inevitably need to accommodate changed circumstances. But it is the enduring features of the environment that provides the guidance for the application and development of technology. Importantly, the absence of the substantial threat provides the opportunity to take long-term views and to build the technological bases necessary for effective force structure development.

The *strategy* which needs to be addressed thus goes beyond the purely military definition:

> The art and science of developing and using political, economic, psychological and military forces as necessary during peace and war, to afford the maximum support to policies, in order to increase the probabilities and favourable consequences of victory and to lessen the chances of defeat.[1]

The problem with this definition is that it assumes a threat as the imperative for action. This is not the circumstance presently faced by Australia. What is of greater relevance is Australian security goals, the principles and priorities for achieving them and the uses to which national capabilities should be put, both to secure and promote the national security interest. Importantly it is national capabilities rather than simply defence capabilities that are relevant.

The nation's defence goals were defined by Government in the White Paper, *The Defence of Australia 1987*:

> The Government's approach to defence is to seek to reinforce the positive aspects of Australia's strategic environment and to provide an appropriate measure of insurance against future uncertainty. The fundamental aspects of that approach are based on:
>
> - maintaining and developing capabilities for the independent defence of Australia and its interests;
>
> - promoting strategic stability and security in our region; and
>
> - as a member of the Western strategic community working for a reduction in the level of tension between the superpowers and limiting the

1 *Australian Joint Services Glossary, JSP (AS) 101(A)*, (Department of Defence, 2nd edn, October 1984).

spread of influences in our region inimical to Western interests.[2]

Within these goals, there are some qualifications. They include a policy of no nuclear weapons, confining consideration to conventional military capabilities. There is also the implicit limitation of power projection in the strategic sense that Australia has no territorial ambitions. But this does not of itself exclude offensive action where this is militarily desirable in the defence of Australia.

The third qualification is that of self-reliance, rather than self-sufficiency. The policy of self-reliance does not of itself prohibit the import of advanced systems. But it does require forces and national capability to employ, maintain and modify such systems so that the defence force is not reliant on direct intervention by other powers for the more credible circumstances likely to be faced.

Further, in looking at future Australian capabilities it is the requirements for the defence of Australia and its direct interests which will have dominant priority. This does not exclude the use of Australian forces further afield in support of wider interests should the government of the day so decide. But forces deployed further afield will be selected because the capabilities developed for defence of Australia are relevant to the more distant scenario.

The Australian strategic planner is fortunate not to be presently constrained by pressing threats to national security. The opportunity exists to look to the long-term security and to shape forces and national support accordingly. The immediate strategic issues resolve to questions of balance in applying available resources to a range of competing demands. Key elements in this competition for resources include the effort in shaping force structures and support for the self-reliant long-term defence of Australia, the demands for capabilities and readiness appropriate to those operational commitments which might arise in the shorter term, and the resources committed to building regional relationships which further reduce the prospects of threats arising.

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2 Kim C. Beazley, Minister for Defence, *The Defence of Australia 1987*, (A White Paper presented to Parliament in March 1987, Australian Government Publishing Service, Canberra, 1987), p.10.

AUSTRALIA'S STRATEGIC ENVIRONMENT

Against this background of national security goals, and in the absence of specific threats, the opportunity exists to shape Australian strategy according to the more enduring features of the strategic environment. Although the emphasis here is on the military applications of technology, it must be recognised that the strategy encompasses wider aspects of domestic and international policy.

Australia is physically remote from the main sources of potential global conflict and from the significant concentrations of military power. We enjoy generally good relations with our neighbours, and regional nations provide a buffer between ourselves and major sources of extra-regional power projection. For as long as the region remains free from external contention, Australia enjoys a measure of insulation. Therefore we share a coincidence of strategic interest with our neighbours.

Outside of mainland Southeast Asia, the region itself consists largely of new nations preoccupied with internal concerns of nation-building. Although cultural differences are wide and periodic strains emerge in regional relationships, there is not, to the same degree, the centuries of cultural enmity which so complicates relationships between societies in Europe or mainland Asia. There are opportunities to build and enhance regional links and associations which could contribute to regional harmony and mutual confidence. Although the present circumstances do not call for more formal defence alliances, common security concerns do provide an avenue for greater understanding and cooperation.

Yet ultimately it is the enduring features of geography which will guide future Australian military application and direction of technology. These features include:

- the absence of land borders;
- the enormity of the land and ocean spaces of immediate concern in relationship to the population base;
- the difficult military operating environment, with its variety of climatic conditions and scant infrastructure; and

- the limitations of the industrial base to sustain technologically advanced military forces.

The key aspect of these enduring features is the comparison of the size of the area to be secured with the relatively small population base. Clearly there are levels of threat with which Australia could have difficulty in coping on its own. This is particularly so if an enemy could achieve a significant lodgement on continental Australia, and bring comparatively larger ground forces to bear. Australia's long-term strategy for the defence of Australia must therefore be directed at raising the threshold of threat for self-reliant defence.

The present trends in the nature of conventional conflict suggest that this threshold will be dictated by the difficulty of any enemy in securing passage to and lodgement on the continent. The sea and air gap is the major obstacle to be overcome and hence a concentration on maritime capabilities is indicated.

But, for best effect, the possession of maritime capabilities must be accompanied by the capacity to position forces and apply them. The total area to be covered is very large and effective intelligence and surveillance will be essential to position forces. Australia's surveillance requirements are severe and in some respects unique to this region. They lend themselves to indigenous research and development.

The geography of the approaches to Australia suggests that air power will be a key component of maritime operations. Australia is well advanced in formulating joint command and control arrangements but further work remains to be done in backing the established structures with the ability to transfer and manipulate information and data. Again, some features of these requirements will be unique to Australia.

The position of ground forces in such a concept is less dominant than would be required for defence within the continent. The ground force would have the roles of securing bases for the operation of naval and air forces and increasing the demands on the size and capabilities of any force about to attempt lodgement. But, to a significant extent, the size and shape of forces to be lodged would be dictated by the geography of the continent. This is not to argue that the Army's role is insignificant but, rather, it is perhaps of a lower priority.

Such a strategic concept for the defence of Australia does not provide an immediate requirement for relevant capabilities to be available in the short term. But what it does provide is a longer term view of potential force structure requirements to assist decisions on the emphasis to be given to long lead time defence capabilities, including national technology, industry and infrastructure support to offer a continuing sense of security into the future and against which more immediate needs for shorter term contingent possibilities can be framed.

Although they are less critical for ultimate national security, the more likely lesser contingencies pose difficult military problems primarily because of the need to achieve solutions for which the costs are not too disproportionate in comparison to the threat, and because they could arise with relatively short notice. Therefore, while presently judged to be unlikely, they do pose more urgent demands on force capabilities and readiness.

The lower-level contingencies do not demand the high level of destructive capabilities implicit in higher level conflicts but will be influenced by the same geographic factors. The essential elements of a concept to combat low-level operations include:

- conventional forces, primarily maritime and air, to control escalation;
- surveillance and patrol of the maritime approaches to avoid interference with routine commercial activities and to limit the scale, frequency and spread of intrusions into Australian territory;
- mobile ground forces to provide security of vital assets, including naval and air force bases and to deal on the basis of hard intelligence from surveillance assets with any intrusions;
- close coordination with civil authorities both for security operations and maximum practicable administrative support to deployed forces;

- the flattest practicable joint command structure to ensure the ease of decision-making and coordinated application of available forces; and
- selected offensive capabilities so that, if necessary, the focus of conflict can be shifted requiring the aggressor to incorporate high cost and extensive defensive measures.

Importantly, although the intensity of engagements will differ between high and low-level conflicts, there is a commmon core of key capabilities required for both. In particular there is a need for:

- extensive surveillance capabilities so that limited forces can be positioned and applied to best effect (in some ways the surveillance task in low-level contingencies could be more demanding);
- joint command arrangements particularly to ensure effective maritime coordination and cooperation;
- mobility, range and endurance of forces to match the substantial distances involved and remoteness of likely operational areas from home bases; and
- an appropriate blend of offensive and defensive elements in the force structure.

In this defensive posture, the strategic aim is to raise the threshold for anyone wishing to take military action against Australia. It will rely on the effective use of selected high technology in key areas to overcome the inherent limitations on military manpower from a small population base. It will require:

- a wide range of technological and industrial support for the self-reliant operation of Australian forces using much imported technology; and
- a domestic technological emphasis on those aspects peculiar to Australia, particularly surveillance and automated assistance to joint command and control.

AUSTRALIA'S STRATEGY

Australia's strategy has been described variously by concepts such as denial, layered defence, defence in depth and deterrence. There is an element of validity in each of these. But it is difficult to find a suitable conceptual or analytical term which adequately covers the full range of considerations essential to a comprehensive strategy directed at influencing Australia's threat environment.

Australia can look to technology to overcome military problems to achieve a sufficient measure of self-reliant defence capability. This involves not only making effective use of the push of overseas technology, but also pulling domestic technology in directions which enhance the defence benefits of our own geography and offset the disadvantages of a small population base.

The intellectual capacity to develop and exploit technological solutions already exists. If there is a weakness, it lies in industry capacity for the support of forces. But in seeking to upgrade these national assets, defence requirements are consistent entirely with the wider sweep of existing government policy.

Australia cannot hope to be self-sufficient technologically or industrially. It should aim to achieve an appropriate balance between imported and domestic technological development. From a military viewpoint, the key domestic emphasis should be on those aspects of the military strategic environment unique to Australia. These centre around the disparity of the size of the area of immediate concern and the manpower base for its security.

The emphasis will need to be given to the maritime approaches. Here the military requirement is less labour intensive, the requirements more amenable to technological solutions, and the sophistication of the industrial base more important to sustaining forces.

Within this the crucial domestic technologies will centre on those associated with surveillance and command and control. It will be necessary to keep close contact with overseas developments in weapons systems and defences against them, but the most significant military problem for Australia is to be able to position and apply forces relatively limited in number to best effect over the enormous distances involved.

Australian strategic thought has advanced considerably over recent years. A self-reliant posture for the defence of Australia against a range of potential threats is achievable within the resources and technological base likely to be available. What is needed most are the widespread public understanding and support for the policy to sustain the effort and the regional acceptance of constructive Australian participation in common regional security concerns.

CHAPTER 8

DEFENCE TECHNOLOGY IN AUSTRALIA

H.A. d'Assumpçao

'...the closest possible connection exists, and will always exist, between science and military affairs.'

Lord Zuckerman[1]

The remarkable advances that have occurred in recent times in technologies such as microelectronics, computers, materials and systems are revolutionising defence equipment. All indications are that this trend will continue, so that even more potent weapons and sensor systems will be available in the future.

There have been numerous instances where high technology has proved decisive in war—for example, effective use of the newly-developed radar gave the Royal Air Force (RAF) a critical advantage in the Battle of Britain. There are also many examples where scientific advocacy has been counterproductive.

Again referring to the Battle of Britain, we find that Professor Lindemann, who had Churchill's ear, vigorously opposed the development of radar in favour of his own favourite technologies—infrared detection and aerial mines of various sorts.[2] As we know, the British only just managed to introduce radar in time for it to tip the balance in their favour. We might speculate whether Britain would have lost that battle, and in consequence the war, had Churchill come to power just six months earlier.

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1 Sir Solly Zuckerman, *Scientists and War—The Impact of Science on Military and Civil Affairs*, (Hamish Hamilton, London, 1966), p.3.

2 See Ronald W. Clark, *Tizard*, (Methuen, London, 1965); and Lord Birkenhead, *The Prof in Two Worlds: The Official Life of Professor F.E. Lindemann, Viscount Cherwell*, (Collins, London, 1961).

Another example is the famous Dambuster Squadron's breaching of the Mohne and Eder Dams in Germany using special bombs invented by Dr Barnes Wallis—an episode immortalised in book, film and the hearts of millions. Through his tenacious—even heroic—efforts, Barnes Wallis managed to convince Bomber Command to divert some of the best RAF crews and desperately scarce resources from other important tasks to this enterprise. Conventional wisdom proclaims that this combination of technological genius with supreme military skill, sacrifice and valour seriously damaged German war production. Sadly, history records otherwise: the effects produced 'were not, in themselves, of fundamental importance nor even seriously damaging'.[3]

There is of course nothing the matter with scientific advocacy in defence or any other field; in fact, progress is slow without it. The point is that the stakes are high: there is much to be gained but the wrong decision can be very costly.

The same care is needed today in judging technological developments. Advanced equipment can benefit Australian defence by augmenting our capabilities. However, systems at the forefront of technology will cost more, will be more complex and, in many cases, will be more difficult to support. The benefits are not always easy to assess and even costs are often difficult to estimate with accuracy.

Of course, merely acquiring equipment does not confer a defence capability—the full benefits are only realised if the equipment is thoroughly integrated into military operations and, it goes without saying, troops are well trained in its use.

It is useful to recall that, at the outset of World War II, Germany had—arguably—better radar than Britain whereas without question the British used theirs with more effect.

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3 The Sorpe Dam, which did supply the war factories of the Ruhr Valley and whose destruction would have had a significant impact, was also attacked. However, its construction was not vulnerable to Barnes Wallis' depth charges—a fact which, it would seem, was known to the British before the attack. See John Terraine, *The Right of the Line: The Royal Air Force in the European War 1939-1945*, (Hodder and Stoughton, London, 1985).

More recent examples have appeared in Middle East conflicts. In many engagements, modern weapons systems of comparable performance were used on both sides. Yet the ratio of losses was out of all proportion to the marginal differences between the weapons themselves. The consistent disparity in results must be attributed to the more effective use of weapons.

TABLE 1

LOSSES IN THE BEKAA VALLEY, 8-11 JUNE 1982[4]

	ISRAELI	SYRIAN
Killed	195	800
Wounded	872	3,200
Missing & POW	15	150
Tanks	30	400
Aircraft	0	90
Air Defence Missile Launchers	0	120

Like every other modern nation, Australia has to struggle with the questions of how much and what level of military technology to adopt, what to buy and what to develop for ourselves, whether to accept something as it stands or whether to modify it, and how to get the most out of that which we already have.

EQUIPMENT ACQUISITION

Every year the Australian Department of Defence spends some $2 billion on equipment purchases, and military equipment is becoming more expensive, with costs rising 3-5 per cent faster than inflation.

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4 Trevor Dupuy and Paul Martell, *Flawed Victory: The Arab-Israeli Conflict and the 1982 War in Lebanon*, (Hero Books, Fairfax, Virginia, 1986).

There are some clear advantages in acquiring equipment from within Australia. However, because of the high cost of designing and developing high technology defence equipment and the very small internal market, it should be no surprise that, in the vast majority of cases, we find it more attractive to acquire equipment from overseas.

Occasionally we develop equipment ourselves. Sometimes we do so because of our peculiar environmental conditions and operational requirements. (Generally, there is little motivation for a manufacturer to modify equipment to meet just our needs.) Once in a while, Australian scientists and engineers come up with a world-beating idea that is worth pursuing further. And sometimes we simply cannot buy what we require.

The procurement decisions are complex and frequently pivot on scientific advice but we cannot rely entirely on our allies for this for a variety of reasons. The advice must be based on a good understanding of our strategic and operational requirements, our environment and method of operation. Often it is wanted in a hurry and frequently sensitive issues are involved.

Further, the tactical environment our allies are planning on is very different from ours. Whereas they can expect close support from a wide range of assets, our units will often operate alone and at a large distance from population centres. In addition, the performance of weapons and sensors in Europe can be very different from that in our physical environment. For example, in the shallow waters to our north sonar behaves differently than in the Atlantic Ocean or Mediterranean Sea; tropical humidity degrades infrared sensor detection range; and the behaviour of our ionosphere affects in a peculiar manner our HF radio communications and the performance of our over-the-horizon radar (OTHR).

Scientific advice is injected at all phases of the acquisition cycle, starting with assistance in defining Staff Targets and operational requirements and continuing until the equipment is accepted into service. Actually, involvement persists through to the evaluation of the equipment in service—for example, by analysis of its performance in exercises. Any shortcomings revealed at this stage can be taken into account in future equipment upgrades.

SUPPORT TO THE DEFENCE FORCE

The materiel accumulated in the Australian defence inventory over the years has a depreciated value of perhaps $13 billion and will increase substantially with current acquisitions. It is evident that every effort must be made to derive maximum value from such a large investment, by optimising its use and by maximising its life.

Because of the size of the investment, improvements of even a few per cent are worth pursuing. Any measure which will enhance the effectiveness of our $4 billion submarine force, or our $5 billion fighter aircraft, or our $4-5 billion ANZAC ships by a small fraction would be worth investigating. Routine maintenance and support of equipment costs some $1 billion annually; some of this is amenable to reduction by skilful application of science.

Support to existing equipment can be divided broadly into four classes: optimising use, extension of life, modification and problem-solving.

Modern weapons and sensor systems can be very complex, with many modes of operation. An operator can easily use the equipment in a less-than-optimal manner. At worst, a totally inappropriate option might be picked, with serious consequences. Thus, technical advice is often needed to optimise the way in which systems are used.

There are enormous advantages in being able to extend the life of expensive equipment. For instance, certain manoeuvres can stress an aircraft's structure and shorten its life; if these can be recognised and avoided, costly replacement can be deferred. Benefits are not measured in cost savings alone. Sometimes, as in the case of the F-111s, there is no realistic replacement; if the life of the equipment cannot be extended, an important capability would be lost.

Since replacement systems strain the budget so severely, Australia tends to keep equipment operating much longer than some of its allies. One should not underestimate the technological challenge of continuing to operate equipment after support from the manufacturer has ceased. Some examples are given in Annexe 1.

It is unusual for a system to remain unchanged throughout its life: there are always upgrades as technology evolves, modifications to adapt to national requirements, adaptations to match emerging threats, and remedies to faults that develop.

Problems frequently arise, in peace as in war, which have to be solved promptly. Many of these are unique to Australia. Some could lead to loss of a capability or reduced life of equipment, and others threaten safety. If a crack is found in an aircraft, an unknown explosive device is unearthed, or a fault is discovered in a weapon's guidance or arming circuitry, immediate action is demanded.

It is not always straightforward to judge what modification and maintenance we should do ourselves and what to have done overseas. Apart from the obvious matter of cost, the most significant question is how responsive we expect others to be, particularly in time of conflict.

Exactly how quick a reaction is needed depends on the circumstances. There is no urgency in many cases but in others, such as electronic warfare, time scales can be very short indeed. Let me give you some historical examples:

- In World War II the British were able to develop countermeasures to German radio navigation aids in a few weeks, drawing substantially on their civil science infrastructure.
- During the Yom Kippur War, when Arab forces introduced a new weapons system, the Israelis evolved countermeasures in a matter of days. The Israelis' ability to respond in this extraordinary fashion was dependent on a technology base built up over the years and thoroughly integrated into their operational procedures.
- In preparing equipment for the Falklands campaign, British defence scientists, in close collaboration with industry, worked around-the-clock on a weekend to modify weapons systems for shipping to the South Atlantic.

Clearly, there will be areas where the necessary responsiveness can only be provided from Australia's own resources. In others, cost may override considerations of timeliness.

SUPPORT FOR NATIONAL OBJECTIVES

There is also the need to carry out some activities in support of national objectives. A good example is work for the Department of Foreign Affairs and Trade, and the Secretary-General of the United Nations, towards chemical disarmament.

THE TECHNOLOGY BASE

To be able to provide timely advice on the acquisition of equipment and on its use, and support on modification, life extension and problem-solving, we must have in this country an adequate technology base—that is, the necessary body of expertise and facilities on which to draw.

With our limited resources, we have to balance carefully the shape, breadth and depth of this technology base. Clearly, we must have scientists and engineers who possess not only technical knowledge and ability but also a good understanding of military operations and of our own environment. But how many, and in what fields? On what should they be engaged?

It goes without saying that we must strive to keep abreast of scientific and technological developments across a wide front, anticipating defence requirements and problems, and always on the lookout for possible defence applications. But the expanse of science is too wide and the number of researchers too few for Australia to aspire to encompass it alone.[5] We therefore have to rely on our allies for scientific and technological information.

A matter of great importance, and one that is implicit in all our planning, is just how much we can rely on overseas sources for expertise, advice and support.

The decisions are often complicated by the reluctance of some nations to release full information on equipment that they sell to us, on grounds of security or commercial confidentiality. Without such information, we have no choice but to depend on the supplier. There is also a lingering doubt whether some nations might, under some

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5 In Chapter 1, Dr Millburn states that even the U.S. can no longer be autonomous in defence technology matters but must rely on overseas support for many critical items.

circumstances, withhold supplies or information from us for political reasons.

Naturally, in research as in every other area, we do not get far if we ask for handouts; to gain access to overseas information we must be able to trade some ourselves and as well to demonstrate that we need and have the capacity to absorb and use the information we seek. It follows that we have to maintain some level of indigenous research capability. We therefore concentrate on a few areas and look to our allies to help us fill in the gaps.

When considering whether to depend on overseas support or to build up our indigenous base, it is useful to assess how quickly a threat can grow in our region, and how much time we would need to react to it.

Because time-scales are so long, we need to anticipate developments in technology and military requirements and to build up expertise well beforehand. There are some obvious principles to be followed in planning and shaping the defence technology base. We begin by looking closely at those areas where defence is likely to make, or has made, large investments. Next we need to focus on where science and technology promises large increases in defence capability. There are also other national priorities that need to be addressed.

In examining the contribution that technology can make to defence capability, we approach from two directions: top-down and bottom-up. We have top-down guidance from documents like *The Defence of Australia 1987*[6] and use these to focus our attention on those issues of greatest importance to Australia.[7] Scientists and engineers also generate ideas and proposals that open up options not previously evident to strategic planners.

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6 Kim C. Beazley, Minister for Defence, *The Defence of Australia 1987*, (A White Paper presented to Parliament in March 1987, Australian Government Publishing Service, Canberra, 1987).

7 Some might consider that such strategic steering inhibits research. I take the opposite view: there is no shortage of exciting research topics, and there is a particular satisfaction in working in a field that is not only scientifically challenging but also likely to find practical application at some future date.

INFRASTRUCTURE

There are many organisations in Australia doing research and development—government and semi-government agencies, tertiary institutions and industry. I shall spend some time describing the Defence Science and Technology Organisation (DSTO) because it is the one most involved in defence research.

DSTO

DSTO is funded by the Department of Defence so it should be no surprise that its program of work is closely aligned with defence priorities. It consists of five Laboratories—two in Victoria and three in South Australia—with a headquarters in Canberra and elements in other States. With a budget of about $200m and a staff of 3,800 it is the second-largest R&D organisation in Australia—about half the size of the CSIRO.

The five areas of activity on which DSTO is engaged are:

- policy advice, especially on equipment acquisition;
- problem-solving;
- development of new equipment;
- building and maintaining the technology base; and
- support to non-defence bodies.

A list of key areas where DSTO conducts R&D is given in Annexe 2.

DSTO is and has been involved in many major acquisition projects, including the F/A-18s, the new submarines and the ANZAC ships, and myriad minor ones. As mentioned earlier, that involvement usually commences with technical inputs during the formulation of the operational requirements, and continues after the equipment is accepted into service.

With the cost of modern defence equipment so high there is a need to solve those problems which threaten to shorten its life. DSTO has a role to advise on proper maintenance procedures and life extension techniques. One such technique, of which we are proud, is the crack-patching of aircraft structures which kept the *Mirages* operational without the expense of complete wing refurbishment. I need not emphasise the benefit of being able to defer the $5 billion fighter replacement by five years.

Much of our problem-solving work is vital to the cost-effective operation of the defence force and it is not surprising that some 27 per cent of DSTO's expenditure is devoted to this activity.

DSTO is probably best known for its major projects such as *Ikarea* and *Barra*. While these projects attract much public attention and have resulted in large overseas sales, taken all together they only account for some 15 per cent of DSTO's effort. However, some of these developments underpin several of the ADF's capabilities.

For example, the *Jindalee* over-the-horizon radar will provide the capability for wide-area surveillance thousands of kilometres from our shore. To achieve the same result with conventional radars would have been prohibitively expensive. Without the capability that *Jindalee* affords, *The Defence of Australia 1987* would have taken quite a different form. It is important to note that *Jindalee* is the result of a bottom-up proposal from defence scientists. It was only after its feasibility was demonstrated that strategic policy was amended to incorporate the broad-area surveillance that it made possible.

The Laser Airborne Depth Sounder (LADS) reflects blue-green laser light from the sea bottom to measure sea depth. This system will allow the Navy Hydrographer to chart coastal areas seven times faster than when using traditional sonar methods.

The development of light, compact magnetic sweeps and simple degaussing techniques has provided the Navy with an affordable mine-sweeping capability using modified fishing vessels. With modest mine countermeasures assets, the Navy will now be able to sweep our ports and harbours in times of emergency.

DSTO has developed a slim-line towed array called *Kariwara*. Its extended array of hydrophones will provide the Navy with a very sensitive underwater detection system for the new submarines. No other Navy has attempted to fit such an array to a submarine of this size—the RAN will be the first.

Because DSTO has resources and facilities not available elsewhere, on occasion we give advice and assistance to non-defence bodies when in the national interest.

CSIRO

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is by far the largest R&D organisation in Australia, with a staff of about 7,000 and a budget of $450m of which a quarter is funded from industry and other government departments. It conducts research in some areas that could be relevant to defence, mainly in the Institutes of Information & Communication Technologies and Industrial Technologies. Programs of work we have identified that the Department of Defence could possibly tap into, if the need arises, are shown in Annexe 3.

From time to time, CSIRO has undertaken research and development projects for defence. One project examined local timber and forest products as a source of nitrocellulose—the main ingredient of many explosives. Precise network timing is fundamental to many defence operations, including satellite-referenced navigation; through another task, CSIRO devised methods for the accurate transmission of timing information via the *Aussat* satellite.

Although there has been low-level collaboration between the two organisations for some time, DSTO and CSIRO are now seeking to strengthen their ties; a Memorandum of Understanding aimed at enhancing collaboration was recently signed. Under its new commercialisation thrust, CSIRO is likely to increase its involvement with defence work in the future.

TELECOM

Telecom Australia has research laboratories at Clayton, Victoria, with a staff of 500 and an annual budget of $40m. There have been formal and informal contacts between DSTO and Telecom Research Laboratories for decades. Telecom is now bidding for some defence contracts; in addition, DSTO and Telecom Research Laboratories are currently setting up collaboration on research into the survivability of communications networks.

ANSTO

Most of Australia's nuclear expertise resides in the Australian Nuclear Science and Technology Organisation (ANSTO), which is centred around the reactor facilities at Lucas Heights in NSW. It has a staff of about 350 and a budget of $17m. It serves the general community on such matters as nuclear medicine and advises the Government on, for example, nuclear safety.

TERTIARY BODIES

Government funding for research in tertiary institutions totals $800m, which is more than the combined budgets of CSIRO, DSTO and all other federally funded research organisations.

The research undertaken in these institutions covers many disciplines. It is mainly oriented towards basic research but is taking on more of an applied flavour as the institutions themselves seek to exploit the fruits of their research.

While there is no systematic attempt by Defence to harness this research effort, DSTO has an ongoing program which sees some $1m being spent each year on specific research tasks in tertiary institutions. In addition, other parts of the Defence Department and the ADF also place substantial contracts direct on these institutions. Some idea of the capabilities of universities and institutes of technology to support Defence can be gleaned from Annexe 4 which shows the list of current DSTO contracts.

INDUSTRY

Industry's role in supporting the Defence Organisation is evolving. We now expect Australian companies to make a greater contribution to our self-reliant defence posture through the supply of equipment and support. I will leave it to my colleague, Dr Malcolm McIntosh, to expand on this in Chapter 12, and confine my comments to industry's role in the development process.

In the development of equipment, Australian industry generally picks up a project at a stage when the technical risk has been reduced to an acceptable level; it then takes it through advanced engineering development, production and marketing.

THE STATE OF AUSTRALIA'S TECHNOLOGY BASE

As a nation, Australia enjoys the benefits of a well-developed science base. In fact, on a per capita basis, we lead the world in the number of basic researchers.

However, the raw figures can mislead because this pre-eminence lacks uniformity. If we use publications as a crude measure

TABLE 2

BASIC RESEARCHERS IN THE POPULATION[8]

Country	No. of basic researchers per 100,000 population
Australia	53.0
Japan	52.6
West Germany	42.3
U.S.	39.1
France	35.4
UK	25.2

of research output, we find that we are strong in medical, rural and some of the social sciences. We are not as strong, and are becoming weaker, in some areas (for example physics and engineering) that are critical to defence.

The extent to which the scientific community can support the Defence Department on a day-to-day basis depends on there being in place an adequate technology base. As outlined above, this technology base resides principally in DSTO.

Several reviews of the DSTO have recognised that its technology base has been sadly depleted in recent times due to economic stringencies and the increased demand from customers for our services. It is interesting to note that DSTO's staff has fallen from 6,000 in 1975 to 3,800 today, whereas defence expenditure on new equipment has increased about seven-fold in the same period. In many key areas, our technology base is either fragile, inadequate or non-existent. Successive Governments have acknowledged this

8 Australian Science and Technology Council, *Profile of Australian Science*, (Australian Government Publishing Service, Canberra, 1989).

TABLE 3

RELATIVE PROPORTIONS OF PUBLICATIONS IN AUSTRALIA

Discipline	Per cent of Publications
Clinical Medicine	31
Biology	18
Biomedical Research	13
Chemistry	13
Physics	8
Engineering	7
Earth and Space	7
Mathematics	2

erosion of the technology base and the need to redress the balance between background work and the responses to customer demands, most recently in the 1987 Defence *White Paper*.

Weak though we are in research areas relevant to defence, our greatest shortcoming is in development—and I suggest that it is no coincidence that that is the activity for which the cost is highest. In Australia, industry has not played the same role in developing defence equipment as in other countries. A consequence is that we are ranked towards the bottom of OECD countries in private sector R&D.

Australian industry has been accused of avoiding investment in R&D, relying instead on their overseas parent companies or contacts. There are some hopeful signs, however. Spending on R&D in business has been increasing, as Table 5 shows.

The dramatic increase since 1984 must be attributed in part to the 150 per cent tax incentive scheme which is currently costing government about $200m per year. Not unexpectedly, most of the R&D in industry is devoted to advanced development and a very small amount to research. There is a claim that this increase results from creative accounting, with companies unfairly redefining jobs as

TABLE 4

BUSINESS ENTERPRISE R&D AS % GDP[9]

Country	Percentage GDP
U.S.	2.07
Sweden	1.97
West Germany	1.92
Japan	1.88
Switzerland	1.70
UK	1.47
France	1.36
Netherlands	1.17
Norway	1.01
Belgium	0.95
Finland	0.75
Canada	0.69
Denmark	0.69
Italy	0.67
Austria	0.65
Ireland	0.41
AUSTRALIA	0.38
Spain	0.23
New Zealand	0.21
Iceland	0.13
Portugal	0.12
Greece	0.08

R&D to make their cost allowable under the terms of the scheme. Whatever the precise figures, there is no doubt that there has been some increase in R&D in industry although it may not be quite as large as shown above.

9 Department of Industry, Technology and Commerce, *Science and Technology Statement—1987-88*, (Australian Government Publishing Service, Canberra, 1988).

A welcome change is industry's ability to retain technologies that have been transferred to them. Whereas in the past technology transferred to industry was short-lived, now we find that at least some companies are taking on the responsibility of keeping these skills alive.

TABLE 5

INDUSTRY EXPENDITURE ON R&D

1976/77	$ 431m
1978/79	$ 430m
1981/82	$ 470m
1984/85	$ 721m
1985/86	$ 846m
1986/87	$1,023m
1987/88	$1,064m

(Constant 1984/85 Prices)

CONCLUDING REMARKS

Without any threat in our region, we have to be sufficiently flexible to cope with any one of a range of eventualities, as well as with the explosive growth of technology which shows little sign of abating. However, with the escalating cost of military equipment we cannot aspire to be at the forefront of technology. The continuing challenge is to ensure that the Defence Department makes best use of relevant technology at an affordable price.

Ultimately, our ability to exploit technology rests on our economic well-being and on our intellectual base and its continual replenishment through the education of our youth. In this regard we are blessed with a culture that encourages education. However, there are disturbing trends: our economy is declining relative to other countries in our region and are we falling behind other nations in education, particularly in fields that will contribute to the generation of wealth. These are issues that concern the whole community, of which defence forms but a part. These are the issues on which, in the long run, our defence technology and the security of the nation will depend.

ANNEXE 1

DSTO'S LIFE EXTENSION AND PROBLEM-SOLVING WORK

Australia tends to keep equipment operating long after support from the manufacturer has ceased; examples of how DSTO has extended the life of expensive equipment and solved problems are shown below:

- DSTO developed crack-patching to halt crack growth in *Mirage* aircraft structures, allowing their life to be extended for many years and the $5 billion expenditure on their replacement (the *Hornets*) to be deferred. The technique is now being applied to prolong the life of the F-lll fleet by twenty years.
- Our allies are generally not as interested as we are in corrosion in the tropics; we have had to solve problems of RAAF antennas corroding (savings of over $1m for an outlay of $23,000) and develop anti-fouling paints to protect RAN ships.
- Our armoured vehicles are subjected to hotter and dustier conditions than NATO; DSTO has developed new rubber compounds for tank trackpads to allow them to survive longer in our harsh environment.
- DSTO and CSIRO have developed processes to allow the use of locally produced cellulose in the manufacture of gun propellants.
- DSTO has investigated the build-up of hydrogen sulphide in ships. This was shown to be due to anaerobic sulphate reducing bacteria in ships' bilges.
- Desealants used to open aircraft fuel tanks for inspection and maintenance were both noxious and foul smelling. DSTO developed a new desealant that was both benign and pleasant in odour.
- DSTO has developed disruptive camouflage schemes for combat aircraft and field uniforms that match our own unique vegetation and soils.

ANNEXE 2

R&D IN DSTO

Optoelectronics: Solid-state materials and devices, lasers, remote sensing, image processing, sensor systems, laser hydrography.

HF Radar: Ionospheric physics, signal processing, over-the-horizon radar.

Microwave Radar: Radar target characteristics, synthetic aperture radar, radar modelling, microwave radar systems.

Information Technology: Software integrity, knowledge-based information systems, software engineering, command and control, very large scale integrated circuits, computer research.

Communications: Radiowave propagation, communications networks and switching, cryptomathematics, communications technology, satellite systems.

Electronic Warfare: Electronic and optoelectronic support measures and countermeasures, signature reduction, electronic warfare systems.

Combat Systems: Human factors, assessment of weapons systems effectiveness, weapons and sensor systems integration.

Underwater Detection: Physical oceanography, underwater acoustics, signal processing and classification, passive and active sonar.

Guided Weapons: Control science, guided weapons modelling, missile seekers and navigation, guided weapons systems, gun fire control systems.

Ordnance: Gun and rocket propellants and propulsion systems, interior and exterior ballistics, ordnance systems.

Explosives: Energetic materials, primary explosives, pyrotechnics, non-linear fluid dynamics, fuses, explosive devices, ballistic protection.

Protective Chemistry: Materials deterioration and protection, chemical defence, pharmacology, mycology, food science and human nutrition, fuels and lubricants.

Materials: Metals, ceramics, polymers, composites, steels and welding technology, performance and vulnerability of sea and land platforms.

Underwater Weapons: Magnetism, underwater sensors, high-frequency sonar, torpedo modelling, marine mines, underwater weapons countermeasures.

Flight Dynamics and Aeropropulsion: Fluid mechanics, computational fluid dynamics, high temperature materials, aircraft engines, helicopter transmissions, aerodynamics research, wind tunnels.

Aircraft Structures: Fatigue and reliability, impact damage, structural vibration, flight loads, structural vulnerability, repair and strengthening of components.

Aircraft Systems: Tactical modelling, human factors, avionics, aircraft systems integration, external stores carriage, flight simulation.

Aircraft Materials: Advanced aircraft materials (composites, alloys), mechanisms of failure, environmental effects, metallurgy.

ANNEXE 3

R&D IN CSIRO RELEVANT TO DEFENCE

Advanced Materials

Applied Plasma Science

Applied and Industrial Mathematics

Applied Optics

Biometrics

Chemical Bases of Food Acceptance

Chemical Conversion

Clouds and Radiation

Design for Durability Development and Application of Advanced Ceramics

Dietary Lipids and Related Factors in Human Health

Electro-optics

Energy Storage

Fabric Performance

Food Structure

Food Safety and Nutritional Storage

High-Technology Systems

Image and Signal Technology

Information Management

Information Technology

Life Cycle Performance

Materials Engineering

Micrometeorology

Microwave Technology

Non-Destructive Evaluation

Ocean Characterisation

Physical Oceanography

Physics of Materials

Polymer Science

Renewable Energy

Safety and Risk

Solid-State Investigations

Spectroscopy

Theoretical Physics

Tropical Ecosysytems Ecology

Water and Wastewater Purification

ANNEXE 4

DSTO R&D CONTRACTS ON TERTIARY INSTITUTIONS

Acoustic Ocean-Bottom Roughness

Active Control of Interior Generated Noise in Submarines

ADA Preprocessor for Declarative Programming

Advanced Target Tracking Algorithms

Aircraft Optimal Trajectory Generation

Cadmium Mercury Telluride Devices

Detection of Faults in Systolic Processing Elements

Forecasting Ocean Behaviour Using SAR and HF Radar

Identification of Engine Faults

Image Insertion

Infrared Measurements in Semiconductors

Infrared Tropospheric Transmission

Ionospheric Ray Tracing Studies

Laser Research

Measurement of Stress in Submariners

Multiplexing and Access Control Techniques—Communications Networks

Radar Target Classification Techniques

Robust and Adaptive Flexible Structure Control

Safety Critical Software Specification and Verification

Sandwave Movement, Current etc., in Torres Strait

Target Recognition with Radar Using Neural Networks

Underwater Acoustic Transients

CHAPTER 9

THE AUSTRALIAN DEFENCE INDUSTRY PERSPECTIVE

John Jeremy

The capability of any nation to defend itself extends far beyond the equipment, skills and training of its armed forces. The strength of its economy, and the diversity and capabilities of its industry contribute the necessary depth of resources to support independent military action. A strong economy and industrial base is in itself a deterrent to a potential aggressor who must recognise the basic strength and staying power these provide.

Since Federation, Australia has largely depended upon primary industries for its income, and has developed secondary industries in an environment of high protection. Defence-related industries grew to satisfy the demands of two world wars and the perceived role of Australia's armed forces as part of global and regional alliances. As the years passed, these industries became less relevant to the country's needs as our relationships with our friends and allies matured, and increased emphasis has been placed on defence self-reliance.

As we approach the next century, there is a growing appreciation of the need for a broadly based economy with a healthy and relevant manufacturing industry, internationally competitive and based upon modern technology.

Recent Australian defence re-equipment projects have placed a high priority on participation by Australian industry at all levels, with the aim of building the high technology, competitive defence industry which can provide a high degree of independent capability.

Provided we can manage the financial and human resource risks associated with these programs, excellent opportunities exist for industry generally to benefit from the impetus given to technological development by these defence projects.

In the last 200 years manufacturing has experienced two major revolutions—we are now experiencing a third. The first was about 200 years ago and saw the introduction of the technologies of steam power and mechanisation. The second occurred a century later and saw the advent of electric and internal combustion motor technologies. Now, another century later, a third industrial revolution is being brought about by the introduction of powerful microelectronics technology, which has led to the microprocessor, artificial intelligence, flexible manufacturing systems, etc.[1]

Advances in microelectronics have made possible major improvements in information handling and analysis which have made major differences not only to the way commanders fight battles and manage their forces but also to how we, in industry, design the weapons and equipment which are required, and carry out manufacturing and manage projects.

Like the two former revolutions, our industrial revolution has to take place during a period of rapid social change, when there are widening differences between those in positions of power and influence and the mass of the world's population—when those with a perceived need for goods and services have not the means to purchase them—when high technology manufacturing countries are financing their own exports through their banks—when the resultant debt imbalances are inevitably leading to instability. These factors present special problems to those in Australian industry faced with decisions as to how and when to take advantage of new technology development. Australian industry has developed (and continues to grow) in response to many pressures—cultural, political, financial and technological. It is what it is today as a result of past pressures. It can be changed only slowly if the whole of Australia's industrial infrastructure is not to be put at risk. Australian industrialists have no wish to face the destruction of their base such as occurred in Germany

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1 H.J. Warnecke, *Methods and Procedures to Increase Efficiency*, (Institute for Production Engineering and Automation, Stuttgart, 1984).

and Japan—but which allowed the rebirth of a modernised industrial base in those countries.

This chapter describes the Australian defence industry; discusses some matters which impact on the way it reacts to advances in technology; and then discusses the effects these advances are likely to have on capabilities, processes, and management systems.

THE AUSTRALIAN DEFENCE INDUSTRY SCENE

The Directory of Australian Industry Defence Capability[2] lists some 650 Australian companies in 99 product categories. The 650 companies employ 291,000 people: 75 per cent are wholly Australian-owned but, in the great majority, defence work represents only a small percentage of their output.

There are 289 plant locations listed on the *Defence Register of Acredited Suppliers*.[3] These are company premises which have been assessed by the Defence Quality Assurance Organisation as having quality systems which satisfy the requirements of applicable Australian quality standards. Presumably they represent those companies whose interest in defence contracts is both substantial and current. The membership of the MTIA Defence Manufacturers' Council (DMC) remains steady at between 220 and 250 companies and includes all major players.

The industry was born out of three pressures:

- First, there was a perceived need by successive Australian Governments to achieve a level of self-reliance in the supply and support of its Armed Forces—especially in relation to munitions and clothing and the repair and overhaul of its ships and aircraft.
- Second, there was the perceived need for overseas-based suppliers of defence equipment to have a

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2 Department of Defence, *The Directory of Australian Industry Defence Capability*, (Directorate of Departmental Publications, Canberra, 1986).

3 Department of Defence, *Defence Register of Accredited Suppliers*, (Canberra, microfiche, May 1989).

presence in Australia—first as a sales outlet, then, progressively, as a spare parts warehouse; a repair capability; a manufacturer of consumables associated with the use of their systems; a sub-contractor building to their design; an assembler, systems integrator and tester; a designer of sub-assemblies; and a developer of products or capabilities for sale on the world market. Not all, of course, followed this path exactly, but the progressive development of capabilities in Australia in this illustration is typical. At present, overseas corporations have Australian interests (perhaps with considerable Australian equity) at every stage of that progression.

- Third (and recently), there has been a number of smaller companies formed to exploit newer technologies and niche markets—especially in the information technologies sector.

Much of the industry established as a result of the first of these pressures arose from the needs of two world wars—and particularly World War II.

Post-war Government recognised the need to retain extensive capabilities in the interests of defence. With sometimes limited commercial application, these capabilities were often kept within government-owned and operated factories, which, isolated from commercial pressures, became dependent upon government funding for their continued existence.

Recent government policy has resulted in the restructuring of the government-owned facilities—eliminating capability no longer relevant to defence needs and introducing the remainder to the realities (and freedoms) of the commercial world through corporatisation or sale.

An intermediate approach has existed for many years with commercial operation of partly or wholly government-owned assets by commercial companies—for example, Hawker de Havilland and Cockatoo Dockyard in the aerospace and shipbuilding/ship repair industries respectively. Whilst able to benefit from their ability to operate in commercial as well as defence markets, organisations like these have usually relied heavily on defence work, as have many of their similar counterparts overseas.

The second pressure resulted in companies which only recently have begun to make significant investment into in-house initiated research and development and to develop extensive export markets.

The third, so far, has resulted in a number of very capable owner-managed companies, very few of which can be expected to continue to grow once the owner-manager leaves the company and many of which are too small to carry the overheads of competing for continuous defence orders.

Many of the companies in the industry are in the process of dramatic changes in ownership or management arrangements. There are also significant new players entering the market. As a result, there is now considerable reassessment of companies' objectives and considerable soul-searching within managements and boards of directors.

GOVERNMENT POLICY CHANGES

Major Federal Government policy changes in the second half of the 1980s have made significant contributions towards making Australian industry a more attractive investment option by turning an inward-looking, protected Australian economy towards international competitiveness. There has, for instance, been a decrease in real wage levels. Australia is facing up to the need to overcome shortages of skilled people.

Further improvements are expected from the comprehensive improvements in industry skill and reforms of pay structures and work practices which are currently underway—especially as these are being linked to a comprehensive strategy for the reform of education and industry training. There are also signs of a willingness on the part of the Australian Government to attack the attitudinal and procedural difficulties which make both temporary and permanent migration of skilled personnel to our country more difficult—such as recognition of overseas qualifications, etc., and the issue of visas.

There is also a willingness to attack the detrimental effects on Australia's competitiveness of Australia's transport and communications sectors. There is great potential for improvement in

the competitiveness of Australian industry in removing barriers and impediments to the efficient provision of these services within Australia.

In industrial relations within our factories and work sites there have also been significant advances. The site agreements for the ANZAC Ship and Submarine projects are hopefully the first signs of a dramatic change in the way unions operate on a work site engaged in a major project.

There are indications that the senior leadership of both management and the unions are prepared to take a longer term view of what constitutes a 'good deal' for their companies or for their membership. This makes the prospects for successfully integrating new technologies into Australian industry so much better.

Of course, there have been difficulties in revising the protectionist policies which have existed for almost a century. Overcoming the structural and production inefficiencies they have created cannot be achieved overnight. But Australian industry and the Australian defence industry in particular are in much better shape as a result.

SMALL SIZE

The Australian defence industry is very small by international standards. Even after a factor is introduced to discount relative populations, it stands well down on the list of defence industries in industrialised countries. There are many reasons for this. It is not relevant to go into all of them in this chapter, except to point out that the economic and defence policies adopted by previous Australian governments over a considerable period played a significant part. Economic policies adopted by these governments saw Australia mainly as a producer of raw materials to manufacturers in other countries, whilst defence policies saw Australian armed forces as being used as 'additions' to the armed forces of Australia's large and powerful allies—with the bulk of the materiel support for the Australian Defence Force being provided by those allies.

There was (and still is to a marked degree) also a national 'holier-than-thou' attitude towards getting involved in the activities of the 'merchants of death'. Indeed, even the military has often been unwilling to actively support commercial activities of Australian defence industries.

EXPORT ORIENTATION

Australian defence-oriented companies had (and continue to have) difficulties in attracting markets for their products.

The Australian defence industry has a proven track record as a competent (but small scale) manufacturer. Its standard of engineering is excellent and satisfies the most demanding customer. In a range of activities and projects, and in a variety of technologies, Australians have shown they have the ability to come up with innovative ideas. The *Ikara* system, which extended the range of a ship's torpedo by using a rocket to launch the torpedo to the vicinity of its target, the *Jindivik* target aircraft and the *Nomad* light aircraft have, in the past, had the potential to achieve widespread international sales.

At present we do have expectations of international sales for *Aster* bomb racks; glide bombs; *Nulka*, a hovering rocket ship decoy system; *Barra*, an aircraft-dropped and monitored sonar buoy; the mine hunting catamaran; water purification equipment using reverse osmosis techniques; sophisticated software packages; and a range of electronic and computer-based equipment in the test equipment and maintenance areas.

But the industry, up to now, has been hampered in its development by a lack of ambition, by inward looking attitudes on the part of some of those responsible for marketing its products, capabilities and services and by industry development policies and acquisition strategies by its major customers which have encouraged 'build-to-print' to others' designs. Some overseas owners of Australian subsidiaries have also seen their Australian operations as a means of satisfying the local market, rather than as a part of a global capability for the world market.

In fairness to those, including this author, who have just been criticised, it should be pointed out that the small domestic market available to the Australian industry has not been a good base from which to launch a sales offensive onto the international market. Australian companies have found it difficult to find projects which are small enough to be capable of being digested but large enough to recover front-end costs and still be price competitive.

The industry, which was previously inward looking, with the Australian Government and its agencies as its sole customers, is now more outwardly oriented. It is more exposed to international competition—more willing to seek out strategic alliances with overseas companies and to go looking for overseas customers. Some companies are making strenuous efforts to get involved in major risk-sharing collaboration ventures to design and manufacture substantial products or major systems for the world market. This is making them more willing to adopt new technologies for both products and processes.

RISK MANAGEMENT

Defence industry has to compete with growth industries like information technology, tourism and property development for the investment dollar. The industry must give shareholders an attractive return on capital commensurate with the risks involved. Increasingly, high value defence contracts are characterised by high cost of tendering, long duration and margins compressed by the competitive tendering process. This makes it difficult to convince investors that returns can be confidently expected, particularly when it is hard to predict the industrial, social and political environment in two years time, let alone ten.

Decision makers in defence projects have differing views as to what constitutes risk. The Department, not so long ago, saw meeting the operational requirements of the Services as the single major goal of a defence procurement project. If higher technology solutions were required to meet these operational objectives they were likely to be adopted, as occurred in the purchase of the F-111. All other considerations (including the possibility of cost over-runs) were secondary. Technological superiority was seen as a goal in its own right—even if this meant that local industry involvement in the projects was negligible. The risk was (essentially) that a Service would finish up with equipment which it then found did not fulfil its expectations or which it could not support.

Now the Department is more concerned with concepts like maximising Australian industry involvement, financial control and project management. Keeping a project within its cost limits and maintaining a high level of Australian industry involvement (AII) are now more important. Risk is more likely to be seen as the probability a project will over-run its cost ceiling or that the prescribed level of AII will not be met.

Under these circumstances, the Department seems to be caught in a two-way squeeze in relation to adopting new technologies:

- the Department likes it, if it is likely to allow it to do more operationally, or if it is likely to decrease whole-of-life costs by increasing the operationally useful life of the product or system;
- the Department dislikes it, if it increases the probability of complications in production, in testing or during its service life.

From industry's point of view, risk is perceived as the probability that the company will fail to get an adequate return for the resources it uses. In these days of competitive fixed priced contracts, there is a natural unwillingness to move away from technology that is tried and trusted.

Barry Jones, Australia's Minister for Science and Small Business in 1989, who has said more on the implications of new technology than almost anybody else, argued on at least one occasion that I know of, that within government, and especially within the bureaucracy, there are two differing schools in relation to the adoption of technology:

- the traditional incrementalists who believe in seeking (and indeed allowing) only incremental changes in existing solutions, technologies and processes; and
- the radical discontinuity proponents who constantly seek the quantum leap forward.[4]

In relation to the design, development and production of equipment for the ADF, in both the Department and within the board rooms of the companies involved in the industry—the traditional incrementalist school is dominant.

4 Barry O. Jones, *National Workshop on Selecting Technologies for the Future: Moving Towards the Sunrise?*, 26 August 1987.

From an industry point of view, this is quite understandable. Despite potential for long-term application in other areas of endeavour, a new technology or process may be so expensive as to demand full cost recovery on an individual defence project. In a competitive environment, with high interest rates and pressure for a high return on investment, it is not surprising if there is some restraint on proposals for radical change.

CHANGING TECHNOLOGY

An additional problem which faces company board rooms, when considering technology investment, is the rapidity of technological change.

Some 90 per cent of all scientific knowledge has been developed in just the last 30 years. The pace of technological change is accelerating beyond the ability of the larger companies to maintain contact with it.

With life cycles of technological innovations halving in the last few years, larger companies find they are being outpaced by the myriad of specialist smaller companies who happen upon a particular solution to a technological problem. Smaller companies, however, find they have not the organisational stamina to fully exploit a breakthrough in the international market place or to maintain their lead by sustained research and development effort.

Alliances between companies are seen as an answer to these problems and, when properly managed, can be so. In their simplest form they can be like the individual in the television advertisement—of the 'like the product buy the company' variety. More often, however, they are attractive because they are seen to combine different, but complementary skills and capabilities, while retaining separate ownership. They are also often considered as a means of reducing the investment load each has to carry to obtain new technologies; to ensure inter-operability within a total system; or (and this is especially relevant for Australian companies) to gain access to international markets.

Furthermore, predicting which revolutionary technology should be backed is notoriously risky. Boards of directors (and governments) can to some extent be excused for preferring the incremental approach to technology development. But our 'experts' have made some real blunders, as the formerly mentioned Mr Barry Jones likes to point out in order to shock his colleagues into some action in support of technology development.[5]

In 1951 the Australian Government stopped CSIRO continuing its pioneering work in computers on the grounds that computing was of no conceivable economic relevance to Australia.

In 1956 a committee of Canberra bureaucrats stopped CSIRO's work on second generation transistors because they concluded that, while semi-conductors were an interesting laboratory phenomenon, it was impossible they could ever replace the vacuum tube.

The wet process colour reproducing machine developed by the DSTO was rejected for the same reason.

In the early 1960s the DSTO at Salisbury was ahead of the rest of the world in the development of direct-viewing far infra-red technology (thermal imaging) but was persuaded to change direction in its research, to concentrate on incremental advances associated with film technology.

In 1968 the Department of Civil Aviation and the RAAF rejected Dr David Warren's 'black-box' flight recorder on two grounds: first, that as there were not many aircraft accidents in Australia there was no need for it, and, second, that the existence of a flight recorder would actually worsen pilot performance and be a cause of accidents.

In the 1960s Australia had some prospects of being a significant performer in space. Australian satellites were launched from Woomera and this country was exporting rockets. However there was a bureaucratic and political failure of will. By 1971 this venture into satellite technology had ended, with some of the equipment being sold off to Sweden and India. Now Australia imports satellites at enormous expense, even allowing for the offsets which could create some space-related capability for our industries. The prospects of a satellite launching facility at Cape York will be an exciting challenge for the private sector in the 1990s, and a poignant reminder of the opportunities lost because of a bureaucratic mind set which was too rigid to grasp the potential of space.

5 Barry O. Jones, *The Sixth Keith Roby Memorial Lecture*, (Murdoch University, Perth, 28 October 1988).

The list could be expanded and brought up to date. There are certainly current examples. Readers can no doubt supply their own.

OBTAINING TECHNOLOGY

Technology for use in Australian defence manufacturing is usually bought in as part of a capital equipment purchase on behalf of one of the Services. Australian industry content of defence purchases is currently some 22-23 per cent of the total Australian defence materiel procurement expenditure. This will rise dramatically as the expenditures for the Submarine and ANZAC Ship projects begin to become evident. As most major defence purchases by Australia involve considerable technology near the leading edge, the technological level of the Australian defence industry has risen appreciably because of the determination of the Australian Government to achieve high levels of Australian industry involvement in its projects. Whereas fifteen years ago, project staff were advised that an objective of 15 per cent for Australian industry participation for a communications or electronics project was all that was realistic, now levels of 50-60 per cent are regularly achieved (and contracted) for similar projects. In addition, the three times multiplier, for offsets credits for technology transfer, has had a major influence.

The F/A-18 Industry Program illustrates how a major defence procurement can be used to increase the technological capability of the Australian defence industry.[6]

As well as raising the competence of the RAAF's test pilots to test flying of advanced weapons systems and raise industry's management skills in complex major projects to ensure adherence to a tight schedule, working with fixed and firm prices and to high quality standards, the project introduced a range of new technologies to Australian industry.

Probably the most important of these was the technological capability to integrate complex airborne electronic systems (radars, mission computers, stores management systems, etc.) with a weapons system.

A host of other important capabilities also were obtained, for example:

6 Information supplied by the Department of Defence, Canberra.

- manufacture of aircraft-standard, large, composite material assemblies;
- manufacture of low tolerance airframe assemblies;
- manufacture of cockpit and windshield transparencies with high levels of optical transmission and very low levels of distortion;
- machining of very high strength steels;
- assembly of precision hydraulic activators operating with great rapidity and powered by very high pressure hydraulic fluid;
- manufacture, assembly and test of an advanced military radar system;
- manufacture and test of a range of avionic systems—such as head-up displays, inertial navigation systems, stores management systems, etc.;
- design and manufacture of computer based automatic test equipment;
- manufacture of flexible fuel cells;
- assembly of precision mechanical components such as gear boxes and auxiliary power units;
- test of high pressure hydraulic pumps; and
- engine assembly, test and component manufacture of modern high power jet engines involving numerically controlled multi-axis machining centres, vacuum furnaces and engine test cells capable of testing engines up to 40,000lb thrust.[7]

PROBLEMS OBTAINING INFORMATION

But there are problems with buying-in technology in this fashion.

First, there is the commercial sensitivity of the enterprise (or government) who is to provide the technology. Companies normally

7 Hawker de Havilland, *Press Release*, 22 June 1989.

display a distinct unwillingness to transfer leading edge technology. Furthermore, they attempt to limit the application of the intellectual property they may supply. When this commercial sensitivity is exacerbated by sensitivities related to operational performance, an Australian defence manufacturer has great difficulty obtaining what the company (or the government) believes has been paid for in regard to intellectual property.

However, recently there has been an encouraging change in the way some policy 'influenciers' in the U.S. view technology transfer. As Mr John O'Brien, Chief Operating Officer of Grumman, told a recent meeting of the U.S. Aerospace Industries Association, 'The future of the U.S. is more dependent on its ability to innovate and create new technology than on its ability to protect old technology'.[8]

Second, there is the 'foreman's notebook' syndrome. Not all information is included in a technical data package—not all permits, concessions, engineering charges, etc., are truthfully recorded. There is hardly a single member of the Defence Manufacturers' Council who cannot provide anecdotes to illustrate how difficult it is to find the 'hidden ingredient'.

PRODUCTS AND SYSTEMS

My colleague Edwin Matuik, Chief Executive of Plessey Pacific, draws an analogy between technology development and the growth of a tree. The point he makes is that a successful company's technological development is well rooted in a fertile high technology base; the trunk is formed by those mature technologies and projects which provide the workload to make the profit to allow investment and to sustain branching out into new technologies, systems and projects.

He points out that Plessey has a vast amount of technology, obtained from either its own research and development, from the Defence Science and Technology Organisation (DSTO) or from its parent, The Plessey Company plc, in the United Kingdom. Projects like *Discon* and *Raven*, two major communication systems for the Australian Defence Force—the former a strategic network and the latter a combat-net radio system—and *Mulloka* and *Sonobouys*, provide

8 Association of Australian Aerospace Industries, *Visit Report: [U.S.] Aerospace Industries Association [AIA] Meeting*, October 1989.

the established trunk on which to build future activities. From these, the company has obtained a sound understanding of the ADF needs in the command, control, communication, information and surveillance business. They provide interesting work and a secure future for a team of scientists and engineers, who can then tackle additional problems in software and electronic design with competence and vigour.

The company has established a reputation for excellence which allows it to win orders against the best in the world. For instance, its reputation in the piezoelectric ceramics area (used in sonar underwater listening devices such as the *Barra, Sonobouy* and *Mulloka*) is such that Plessey has won a contract from the major French firm (Thomson-Sintra) to design, develop and supply transducers and front-end conditioning electronics for the *Scylla* sonar systems in the RAN's new submarines.

Plessey, with its partner in Sonobouys Australia (AWA), is looking optimistically at the world sonar market—a market estimated to be worth $700-$1,500 million over the next 10 years.

The company is already selling hybrid circuits to Japan and piezoelectronic ceramics to the U.S.. The company is also competitively selling parts for main attack sonars to Krupp-Atlas of West Germany.

With the sale to the U.S. Army of frequency management software developed under the *Raven* project by Computer Sciences of Australia, the company sees a great opportunity for the Australian defence industry.

British Aerospace Australia has had a similar experience to Plessey, but its technological development is rooted in different ground (if we use a similar analogy to the growth of a tree). BAeA has grown from two British companies who came to Australia in support of the Woomera rocket trials. These two companies were English Electric and the Bristol Aeroplane Company. The Wilson Labour Government in the UK saw them rationalised and amalgamated and the Thatcher Government saw them privatised. Now British Aerospace is Britain's largest export earner and the Australian subsidiary, BAeA, is an all-Australian electronics company with

interests ranging from space systems (both space and land segments) through to complex systems in support of the Department of Defence.

BAeA has also obtained its vast technological base from its parent company in the UK and through its associations with DSTO and other overseas high technology companies. Projects such as the Avionics Fault Tree Analyser (AFTA) for the F/A-18 aircraft have provided the electronic and systems 'know how' which have enabled the company to grow into Australian's leading space company, with contracts to manufacture space hardware for *Aussat B* series satellites and to upgrade Australian's remote sensing capability. Indeed, defence contracts now comprise only 60 per cent of BAeA workload. This is because the defence market is shrinking, compared with the total market for high technology products.

In recent years there has been an encouraging increase in indigenous R&D activity. The amount spent on R&D by Australian defence manufacturers has increased significantly. Despite this, it is still true to say that the major source of technological innovation (other than foreign sources) for the Australian defence industry is the DSTO.

There are major changes occurring in the DSTO, aimed partly (as the Chief Defence Scientist has described in Chapter 8) at making better use of the DSTO to help industry develop and utilise new technology. DMC members believe that the industry and the Organisation working together can make better use of modern technology to design and create mechanical, optical and electronic devices. The role of the DSTO should be to develop and prove concepts and to demonstrate technology—that of industry to develop, produce and market products and operational systems.[9]

There is evidence that the changes are having beneficial effects and that industry and the DSTO are working better together.

It must also to be pointed out, however, that there are still a number of those who believe that transfer of technology from the DSTO to industry will never be fully effective until the ratio between scientists and support staff in that organisation is drastically changed—with the number of support staff being reduced.

9 *Review of DSTO Salisbury Engineering Facilities*, April 1988.

PROCESS TECHNOLOGY

Manufacturing enterprises think about new technologies at two levels:

- strategically—in terms of markets and products; and
- operationally—in terms of their manufacturing technology.

In this section, I will concentrate on the impact of the microprocessor technology on manufacturing processes. I briefly examine the factory of the future and then discuss two microprocessor applications—robots and CAD/CAM.

FACTORY OF THE FUTURE

The factory of the future will be characterised by a strictly organised information and material flow which will be extensively supported by a hierarchy of computers. Many procedures will no longer occur progressively but simultaneously. As is already happening in the manufacture of integrated circuits, design, development, manufacture and quality control can occur simultaneously.

Until relatively recently, technological developments in manufacturing processes have been essentially concerned with improving the efficiency of the current process - for example, increasing spindle speeds, decreasing cutting times, etc.

Now the emphasis is on reducing the lead times between an order being placed and a customer being satisfied, reducing setting up times, getting work details quicker to the work place, improving inventory control and product distribution systems and on satisfying the customers varied specialised requirements for unique operational features and design characteristics.

To remain internationally competitive, an Australian manufacturer has to increase both productivity and flexibility. Previously these were contradictory requirements. Highly productive high technology innovations (such as the installation of a specialised machine) could be an asset in regard to the increase in productivity it produced, but be a liability in regard to its inability to adapt to altered requirements.

The aim of an investment in technology is not only to increase the efficiency of the manufacturing machines but also to increase the efficiency of the total process by increasing the utilisation of whatever manufacturing capacity is installed as well.

Some 8670 hours a year are potentially available for manufacturing. Studies have shown that only a small percentage of them are actually used in most production plants. In a typical one-shift machine shop, for only approximately 10 per cent of the time are the machines actually productive. The remaining time has to be used in getting manufacturing information to the machine, setting up, changing tooling, getting materials, checking, operator rest breaks, etc.[10]

There are obviously big gains in productivity to be achieved by getting more productive hours.

This is where the impact of the rugged microprocessor, capable of operating in the harsh environment of the factory floor, is having its greatest effect.

In conventional, manually operated systems, manufacturing information is supplied to the operator in written instructions. The machine is idle whilst this is digested, and the tooling selected and set up, and the work prepared. The work is then carried out and the machine is again idle while it is checked and prepared for shipment. All actions were decided upon and carried out by the operator.

More and more of these actions are being automated and microprocessor controlled. In a modern highly technological manufacturing system, design informatian is developed and stored in computers, and production information is determined and transmitted to the appropriate machine with minimum human interaction. Tooling is automatically selected and placed in position. Work is prepared in magazines which are transported around the factory by a transport system which is driverless and also microprocessor controlled. The individual machine operates without human involvement, to the instructions prepared by the computer, carries out the work, checks that work, records and stores the critical information on dimension, etc., and re-magazines the work for further transport.

10 Warnecke, *Methods and Procedures to Increase Efficiency.*

Flexible manufacturing systems go further by interlinking several such machines in an automated material and information flow system—all controlled by a computer.

In the extreme case, each work piece in the magazine is different, so that a manufacturing centre can produce (overnight and without supervision) all the various parts required to assemble a product. The manufacturing centre can be capable of monitoring itself. Sensors measure the wear (on breakages) of tools, measure and then control the process, record its work, diagnose and rectify failures.

ROBOTS

Industrial robots were first used in manufacturing as long ago as 1963. These robots were hydraulically driven with five axes of movement and were particularly suited for such tasks as spot welding and spray painting. They were therefore quickly adopted by the motor vehicle assembly industry. By the end of the 1970s a few hundred had been installed in Australia.[11]

The current generation of robots are more sophisticated, offering greater speed and accuracy, better mechanical design, more scope for interfacing with other machines to form a manufacturing cell, options for the use of sensors, a limited level of artificial intelligence and better programming facilities.

According to the Centre for Robotics and Automation at the Chisholm Institute of Technology, Australian manufacturing has about 1,000 industrial robots installed in approximately 400 locations.[12] Nearly half of these are installed at the five car manufacturers, with Ford having about one-third of the total population in Australia. Outside the car makers, the majority of installations have one or two robots. Applications are estimated to be:

arc welding	35%
spot welding	23%
materials handling	20%
finishing	10%
assembly	5%
other	7%

(Approximate figures)

11 NSW Government, *Advance*, December 1988.

12 Ian McMichael, 'Address to Members of the Metal Trades Industry Association', Melbourne, 2 August 1989.

Despite an upsurge in sales, Australia's robot population in its manufacturing industry is small—even allowing for differences in populations. Our figure compares badly with Japan (100,000) and even the U.S. (30,000) which is becoming desperately concerned by its failure to keep up the technological development pace of the Japanese manufacturing industry. There are hopes, however, that with more Australian companies, especially those with interests in defence manufacturing work, adopting an attitude of continuous improvement to all manufacturing and quality procedures and with improvements in technology by the provision of industrial robots with more flexible programming to minimise the dislocations in production caused by the small (by world standards) batches Australian manufacturers produce, we can expect to see robots used in Australia manufacturing more and more often.

CAD/CAM

With its emphasis on build-to-print work for overseas systems for the Australian Defence Force and its limited past exposure to international competition, Australian defence manufacturers have been slow to adopt computer-aided design and manufacturing systems.

Up to now, introduction of these systems has been hampered because there have been many design engineers who were unfamiliar with working with computers and because the high investment costs (for both hardware and software) made investment decisions difficult— especially for smaller companies. In particular, many smaller enterprises complained that CAD/CAM systems were designed for large or medium sized operations and were not suitable for their purposes. The emphasis, in the 1970s in particular, on 'build-to-print' for defence projects—in the interest of reducing technical risk—also held back the introduction of CAD/CAM in many areas.

In recent years, however, there has been increased emphasis on competitive fixed price contracting and a general freeing of the Australian economy. This has been coupled with a realisation that an overseas designed weapons system may not be completely suitable for the Australian operational environment and can be modified to meet Australia's needs, at acceptable costs, in Australia.

These factors have placed considerable pressures on Australian defence manufacturers' design capabilities. With the increased acceleration of technical progress and the increased emphasis on cost reduction, the planning and organisation for the development and manufacturing of products have become increasingly important.

This, in turn, has already led to heavy investment in computer-aided design and manufacturing systems in Australian manufacturing systems—which will increase at an accelerating rate in the near future as companies try to overcome bottlenecks in their design and project planning departments.

This trend has been helped by the dramatic drop in prices (per bit of information) for both hardware and software and the fact that more and more computer literate graduates and technicians are becoming available. A big upsurge in the use of CAD/CAM is confidently predicted.

MANAGEMENT SYSTEMS

Modern technology has produced major changes in the way defence manufacturing is managed— both in regard to the monitoring of a project by the Department and the control exercised by the prime contractor throughout a project's many layers of sub-contractors.

At the level that outsiders would instantly recognise, the facsimile has increased the tempo of decision making. No longer do managers have the luxury of consideration time, while letters, drawings and documents pass slowly from place to place. The fax flashes information around the world in minutes. In larger organisations, networked computers talk to one another in milliseconds and pass prodigious amounts of data.

The availability of this data has spawned a new industry—that of the analyst. Nowhere has that personality found a more conducive environment in which to prosper than in the Australian Defence Department. The detailed trade-off studies now expected in the management of defence projects have meant that companies have to obtain greater scientific and engineering capabilities within their organisations—just to access the market.

These capabilities are expensive to establish and difficult to maintain. They tend to be specialised to the extent that they are not readily 'sellable' when the need for their services passes.

There is a massive amount of information required in the marketing and tendering in a defence project. AWA's tender for the *JORN* (Jindalee Operational Radar Network) contract is reputed to contain 100,000 pages.[13] Providing this information is very expensive—Hawker de Havilland is reputed to have spent over $4 million on tendering in one recent year. AMECON is believed to have spent about $20 million (over and above that funded by the Government) on the ANZAC Ship Project so far.

While there may be a single project office in the Department, there are many departmental officers in numerous other areas who perceive it as their responsibility to have an informed opinion on one or more aspects of every capital procurement project. The committee system within the Department of Defence encourages this. Modern information technology means that they now have considerable access to raw data on which to base their assessments and have ample opportunity to closely analyse all aspects of a project—no matter how esoteric. This introduces considerable delays into the decision making processes. 'Paralysis-by-analysis' occurs.

To win a contract, a company must be prepared to establish information systems comparable with defence requirements for accounting, management of work progress, technical control, configuration management, quality control, security and training. These are expensive, involving considerable investments on which shareholders seek a reasonable, competitive return.

Too often the cost impact of this thirst for reported information is not fully appreciated. Within the Department there is an emphasis on public accountability and regulation which feeds a requirement for more and more information and the technology to cope with it. The net result, unfortunately, is that fewer and fewer Australian companies are willing to do business with Defence—relative to the dollars the Department is spending on manufactured goods and engineering services of Australian origin.

For the management of the Submarine project, the Australian Submarine Corporation (ASC) is developing a sophisticated computer

13 AWA, *Press Release*, 5 September 1989.

based management information system as the basic tool for managing that complex multi-billion dollar project.[14] The system includes a number of powerful computers supplied by several different manufacturers (DEC, Sequent, Sun) networked together with a large number of personal computers (Apple Macintosh) and work stations (Sun). Various software systems cover:

- cost schedule control;
- contract monitoring and control;
- vendor-furnished information;
- manufacturer resources planning;
- configuration management;
- logistic data management;
- documentation production;
- human resources and time collection; and
- payroll, general ledger and fixed assets.

These are accommodated and brought together in ASC's overall management information system. The focus is integration to ensure that information flows between the various functional data bases within the company to enable efficient control of this huge project.

Flexibility in regard to selection of appropriate hardware for a particular application, yet being able to link different makes and models together in a compatible network, is possible because of careful selection of network protocols and data base software.

It is believed that, when completed, the scope of the ASC management information system will be unique in Australia and the match of any such system anywhere. Certainly it is providing a challenging working environment for graduates in the computer-related fields enjoying professional careers with the company.

The ASC management information system interfaces and is compatible with the CMACS (Contract Monitoring and Control

14 Information supplied by the Australian Submarine Corporation.

System) developed for the Department of Defence by BHP Engineering.[15]

CMACS is used by the Department to monitor and control the execution of the Submarine project. Contract control is achieved by the continual comparison of the planned performance which was submitted by ASC (in a suitable structure) as part of its tender with the measured performance of work after contract award. Measurement of performance is the prime activity of CMACS.

Performance is measurable in four parameters—scope, cost, time and quality. Of these, quality is assured by measurement; adherence to the specifications is not directly addressed by CMACS, although a significant failure to meet defined quality standards will probably be reflected in the measurement of time.

The plan for the projects scope, cost and time is defined for each level in the work pyramid in a hierarchial structure—the sum of all the elements representing the total. The parameters and the objectives in the plan were defined by ASC (or one of its sub-contractors) in its tender and were agreed during contract negotiations as being those against which to monitor and control performance of the work.

Modern information technology allows early identification of deviations from the plan—allowing, in turn, corrective action to be taken at a time when it will require the minimum of effort.

CMACS:

- handles more than one contract and identifies each subcontract in the control framework;
- extracts information from its data base to carry out analysis of alternative solutions or proposals;
- integrates time and cost;
- handles many foreign currencies;
- handles many differing basis of pricing or escalation formulae;

15 Information supplied by BHP Engineering.

- handles many differing payment conditions;
- produces progress reports and certificates;
- calculates and produces progress charts;
- reconciles actual progress or escalation claims with anticipated claims;
- calculates the effects of possible movements in escalation rates or foreign currency exchange rates;
- produces financial status reports which compare actual costs with budgets;
- calculates current estimates of completion times and costs;
- calculates detailed cash forecasts for five year planning; and
- has the capability to automatically or manually rephase forecasts.

CONCLUSION

As we approach the end of this century, the Australian defence industry is changing rapidly, with new technology providing opportunities for the industry to benefit from market growth across a wide spectrum of products.

Once perceived by many people as a rather boring and tedious backwater, the defence industry is developing a new and challenging image. Major projects like the Type 471 submarines and the ANZAC frigates have become national projects attracting widespread support and media attention. This high level of interest will encourage the best people to join the industry, further strengthening the industry and its potential to expand into other markets, both in Australia and overseas.

A secure future for the industry is, of course, far from assured. The international defence market is highly competitive, with nation competing against nation, rather than company against company. Australia is still inexperienced in this environment.

Australia has no monopoly on high technology. It is available to all people—at a similar price. Most countries are seeking to build up their industrial base, often through defence work. If Australian

industry is to succeed, it must have something special to offer the world—and that is likely to be a special level of technology—developed in Australia and substantially owned by Australians.

This will demand increased research and development, and ownership of the results of this work, a trend which is at least partly encouraged by present government policy.

No country can hope to do everything, and Australia must not fail to recognise that substantial links and partnerships with overseas industry will be essential if we are to play a part in the world market.

Tendering for defence work is expensive, both in money and opportunity cost, and profit may not come for years. If large, strong corporations are to remain interested in this market, returns must be competitive with those available from less demanding market sectors. There must also be an equitable distribution of risk between the customer and contractor.

Despite these words of caution, there are good prospects for Australia to have a modern, efficient defence industry by the turn of the century. The challenge then will be to sustain the benefits, both to our economy and to Australia's and the region's defence and industry infrastructure.

CHAPTER 10

UNDERWATER TECHNOLOGY DEVELOPMENT

P.R. Hart and A.C.O. Gibb

According to *The Defence of Australia 1987:*

> The threat to Australia from submarines is low. Nevertheless, because the necessary skills are difficult to acquire and the lead times for adapting and developing anti-submarine warfare (ASW) technology for the Australian environment are long, we need to maintain our expertise in anti-submarine warfare.[1]

In what follows we shall first tell a series of short historical parables from the early days of sonar. We have chosen these examples from the underwater technology field for their interest and to show the opportunities and problems we face as we try to keep alive a technology base in this important area of technology. Australia has a rather long history of involvement in the forefront of the work. In the second part of the chapter we will attempt to draw out the morals from the parables. The development of sonar provides some excellent object lessons for us. The third part relates these observations to the future for underwater technology in Australia.

THE EARLY HISTORY OF SONAR

The use of underwater sound transmission has its origins deep in the past. Leonardo da Vinci naturally had something sensible to say on this subject as on so many others:

1 Kim C. Beazley, Minister for Defence, *The Defence of Australia 1987*, (A White Paper presented to Parliament in March 1987, Australian Government Publishing Service, Canberra, 1987), p.38.

> If you cause your ship to stop and place the head of a long tube in the water and place the outer extremity to your ear, you will hear ships at a great distance from you.[2]

His remark contained, as usual, many valuable insights. He covered the physical process—creation of sound energy in water by the movement of a ship and the transmission of that sound through water. He described the experimental apparatus—a device to couple to the medium (tube) and a processor (human ear and brain). He even had a plan for use when he pointed out that one's own ship's noise could be reduced if the ship was stopped. It was left to many subsequent experimental scientists, theoretical scientists and engineers to convert his observation into working devices to detect and locate ships.

Velocity of Sound in Water

Measuring the speed of sound in water was the place to start. The first experimenters used swimmers armed with clocks who listened for an underwater bell. A more successful attempt used the simultaneous ignition of a flash and the striking of an underwater bell. This came up with the value of 1435 metres per second in fresh water at 8^{0}C (see Figures 1 and 2).[3] The next step was to assess the effects of temperature and salinity. The first record of an Australian contribution to the science was by Richard Threlfall and John Adair. They attempted to measure the velocity of sound in salt water near Port Jackson in 1888. (The centenary of their experiment was perhaps not celebrated in the Australian underwater technology community because the results obtained were rather inaccurate. It is probably also significant that their efforts were not followed up in this country until well after World War II.)

2 E. McCurdy, *The Notebooks of Leonardo da Vinci*, (Garden City Publishing, Garden City NY, 1942), Chapter X.

3 M. Lasky, 'Review of Undersea Acoustics to 1950', *Journal of the Acoustical Society of America*, (Vol.61, No.2), February 1977, pp.283-284.

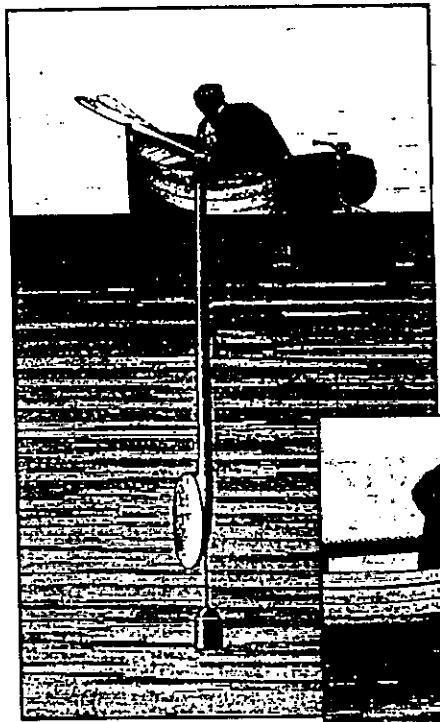


FIGURE 1:

BATEAU EXPEDITEUR DU SON

FIGURE 2:

BATEAU RECEPTEUR DU SON

These and the following figures in this chapter are reproduced with the permission of the Acoustical Society of America.

Hydrophone

The technology paused here to wait for someone to develop an effective device for getting the sound energy out of the water. The acoustic tube and its adaptations relied on an air transmission path from the sensor to the human listener. Fitting the watery end of the tube with rubber bulbs created an omnidirectional sensor and captured more energy, more reliably than an open-ended tube.

The original trumpet-shaped tubes with their curved ends had some directivity. Adding a second bulb restored this property to the rubber bulb sensor. Two acoustic tubes brought the sound up to the operators' ears. Binaural processing in the human brain completed the first sonar system. With this passive listening device the operator could now detect another vessel, locating its direction by swivelling the apparatus until a maximum was found. He could resolve 180^0 ambiguities by searching for a maximum in one ear. He could perform crude classification using his experience of the sound signature of various classes of vessel. He could even make rough range estimates from the intensity or weakness of the detected signal.

At the beginning of World War I, the Royal Navy (RN) confronted three problems. First, the Admiralty saw the potential for underwater sound transmission to help its ships avoid collisions with each other, with the shore and with floating obstructions. The fate of the *Titanic* in 1912 tended to concentrate attention on the use of sound to detect such obstructions. Second, the Admiralty saw a need for its surface ships and shore installations to talk to its own submarines and vice versa. Finally, it was aware of the need to detect enemy submarines from the surface and enemy ships from submarines.

The dual thrust of the requirement—underwater communication and underwater detection—concentrated development on the creation of two devices—an emitter to inject narrow-band focussed energy into the sea and a tunable, sensitive detector to recover energy from the medium.

Carbon microphones, geophones and magnetophones were tested as detectors as well as the rubber acoustic bulbs. Pneumatic, magnetic and piezoelectric devices were tested as transmitters. Eventually devices based on the piezoelectric effect were found to offer the best promise of being both a detector and transmitter of sound energy. Further improvement in detection devices was subordinated to development of a piezoelectric emitter of ultrasonic energy.

By 1917 the British had developed a quartz hydrophone transducer that was to be the backbone of underwater work right through to the end of World War II. In fact, the Admiralty was so sensitive to the potential security of the technology that for many years they insisted that all reference to quartz as the piezoelectric material be censored and that it should be known as asdivite.

Supply of suitable quartz was a problem. The first asdivite transducers were cut from a large and perfect quartz crystal that had been exhibited in the window of a jewellers shop in Paris. As consumption grew quartz mineral crystals were gathered from around the world. At one stage when quartz was in short supply the Admiralty threatened to raid the crystal exhibits of British museums for supplies.

Cutting the quartz to a suitable accuracy was also a problem. At first the slabs were sawn by monumental masons. This was slow and inaccurate. As war became imminent in the 1930s, their technology for cutting the quartz could not keep up with the increased quantities needed. The Admiralty engaged a Belgian firm to supply sintered diamond steel-cutting wheels which reduced the cutting time considerably. The program was so dependent on these wheels that, at the fall of Belgium in 1940, the RN sent a special rescue mission to Antwerp to seize the contents of the factory and all key staff, who were expatriated to Leeds for the duration of the war.[4]

The U.S. Navy took a different approach to the design of hydrophones. They preferred to use artificially produced piezoelectric material in their transducers because:

- It had a superior performance to quartz in terms of energy output and bandwidth; and
- It could be manufactured in the U.S. thereby ensuring continuity of supply.

4 W. Hackmann, *Seek and Strike—Sonar, Anti-Submarine Warfare and the Royal Navy 1914-54*, (Her Majesty's Stationery Office, London, 1984).

These Rochelle salt transducers had one significant disadvantage in that the material was water-soluble. The U.S. developers had great difficulty in packaging the transducers so that they were protected from the marine environment.

Signal Processing

The first listening devices employed in active service used the human ear as a receiver (see Figures 3 and 4 which illustrate the SC device).[5] No better processing system was developed in World War I.

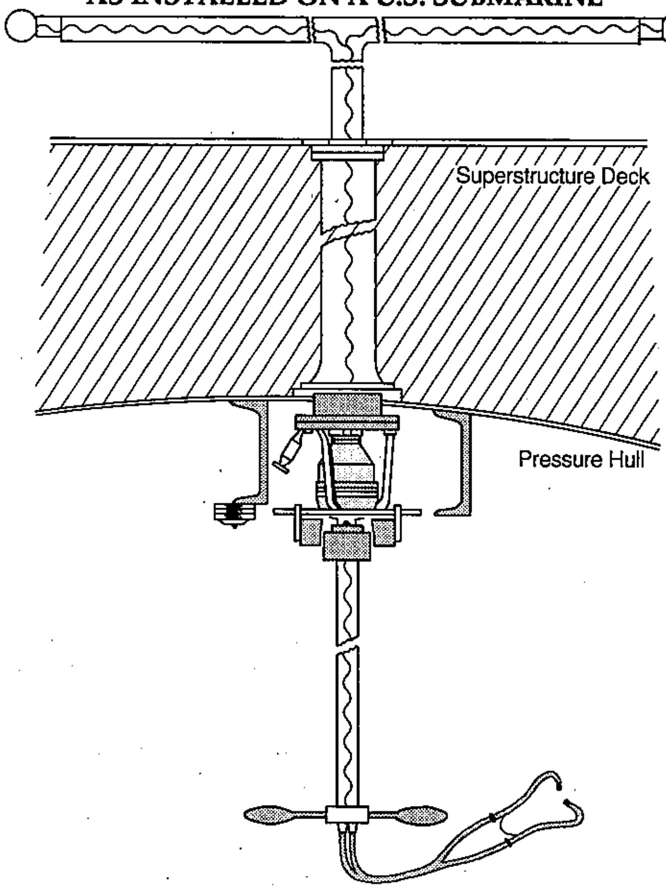
The observer had to be physically close to the sensor to limit the length of the air transmission path. The development of transducer-type detectors, microphones and eventually the quartz hydrophones, changed this. Shielded conducting wires could transmit the signal from the detector to the observer. This had two advantages. It removed the need for the observer to be physically close to the hydrophones and it opened up the possibility of using electronic amplification, delay and filtering of the detected signals. The first valve amplifiers were tested in 1917. Electronic delay compensation was tested in the U.S. in 1918.

The combination of hydrophones and crude electronic signal processing allowed the operator to measure bearing without having to make the hydrophones move physically. The way was then open to mounting passive devices in fixed installations on the hulls of ships and submarines.

A divergence between detection techniques also developed associated with the frequency of operation of the sensor devices. Passive listening installations generally operated at frequencies below 1000Hz. Simple amplification and delay provided an audible output. Active transducers operated in the ultrasonic region between 15000Hz and 40000Hz. These frequencies gave the best energy output. The received echo at ultrasonic frequencies had to be heterodyned down to the audio range of the human ear for processing in the brain. This raised the level of electronic processing needed.

5 E. Klein, 'Underwater Sound and Naval Acoustical Research and Applications Before 1939', *Journal of the Acoustical Society of America*, (Vol.43, No.5), 1968, pp.933-934.

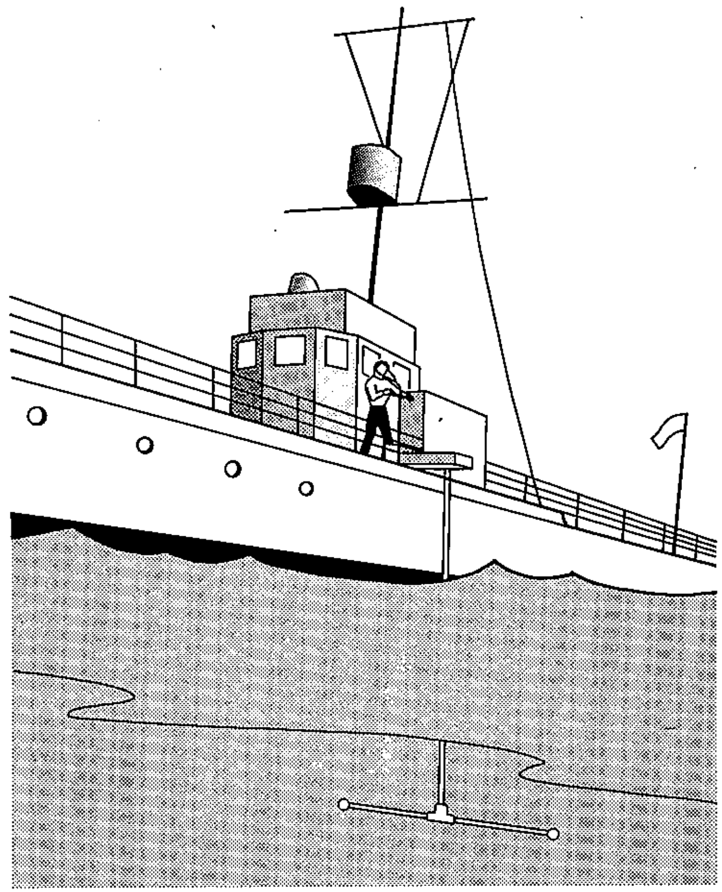
FIGURE 3
TYPE SE-4314 (SC) SOUND RECEIVER AS INSTALLED ON A U.S. SUBMARINE



The most sophisticated system developed during World War I was a towed array of hydrophones. The towed array system included an alterable electrical compensator. This altered the delays between the signals returned from the various parts of the array so as to form sonar beams. The system was tested behind the destroyer USS *Jouett* in trials in April 1918 (see Figure 5).[6]

6 Lasky, 'Review of Undersea Acoustics to 1950', p.289.

FIGURE 4
THE SC TUBE ON A PATROL BOAT

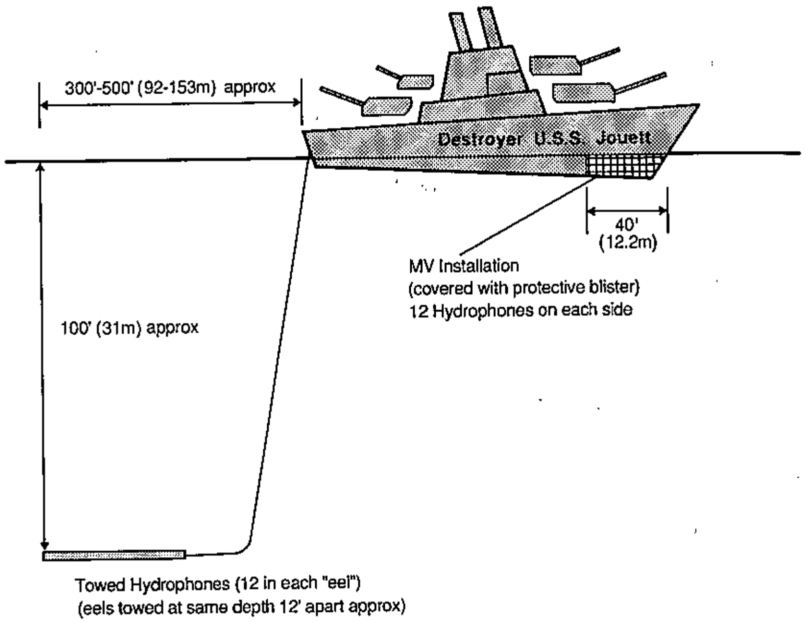


Deployment

With the development of the dual-purpose transmitting and receiving hydrophone the attention of the scientific and experimental workers began to concentrate on active sonar technology to the neglect of passive technology.

The first hull-mounted receivers were tried in 1917. They were very sensitive to hull-transmitted vibration. Two solutions were

FIGURE 5
TOWED HYDROPHONES TRIAL WITH THE USS *JOUETT* - 1918

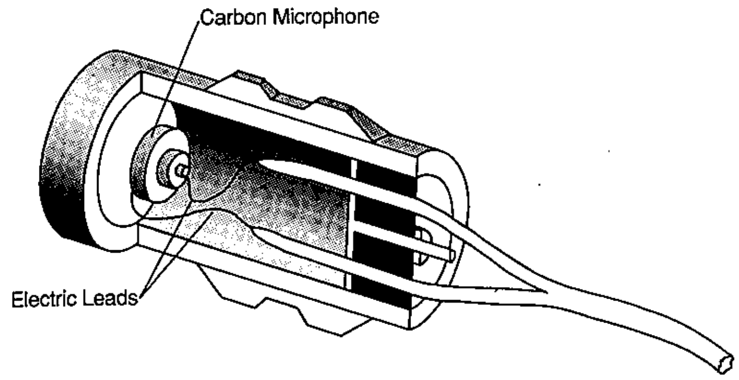


apparent—to quieten the ship or to move the hydrophone away from the source of the noise. Both were applied.

The simplest method of quieting the ship was to switch all systems off. This technique was applied by the commander of a submarine who used the hull-mounted hydrophones to listen for targets and attacking vessels. Turbulence around the hydrophone was also a problem. The RN put a considerable amount of effort into designing ways of reducing water turbulence in the vicinity of the hydrophone. The most successful proved to be the construction of a dome over the protruding hydrophone or hydrophone array. By the beginning of World War II the Navy had developed an effective and durable sonar dome which streamlined the flow of water around the hydrophone and reduced the noise-level contributed by the listening ship.

Moving the hydrophones away from the ship also reduced self-noise. The first towed hydrophones were tested on tow from the back of a ship in 1917. The so-called *RAT* (Figure 6)[7] contained carbon

FIGURE 6
THE *RAT*



microphones inside a rubber water-proof housing and could be used in a binaural manner with one receiver for each ear. By April 1918 the U.S. Navy had an array of hydrophones on tow at 100′ depth and 300′-500′ behind the destroyer USS *Jouett*.

Mounting the hydrophones on shore also reduced noise. The first Director of the Admiralty Board of Invention and Research (BIR) in 1916 was the Australian scientist, Sir William Bragg. The BIR was set up to conduct research and development in underwater detection and communication. His son, later Sir Lawrence Bragg, was at the time an officer in the Army Sound Ranging Corps in France. On a visit to his father he described the technique of sound ranging to staff of the BIR. An array of microphones spanning about six miles measured the time of arrival at each microphone of the sound of an enemy artillery

7 Klein, 'Underwater Sound and Naval Acoustical Research and Aplications before 1939', p.935. (The *RAT* was named for its rodent-like appearance.)

discharge. By correlating these times the Corps could get an estimate of range and bearing to the firing battery. The underwater analogy was immediately apparent and several underwater sound ranging arrays were set up on the south coast of England and in the English Channel. These were able to locate the sources of explosions very accurately and were used to monitor naval bombardments and minefield explosions.[8]

Processing

The UK and France led the development of sonar technology until the U.S. entered the war in 1917. Even at the height of the conflict there was little sharing of information between the two powers for fear of post-war obligations. The entry of the U.S. changed this and a significant transfer of technology from the UK and France to the U.S. took place at a series of briefings in 1917. This had the effect of changing the emphasis of development from investigation of new techniques to production of effective aids to the serving sailor. By the end of the war a large part of the Allied fleets were equipped with U.S. made SC devices—our old friend the binaural air tube steerable listening device.

Research in the U.S. in the 18-month period of its involvement in World War I moved ahead in leaps and bounds. In that short period new techniques were developed. Electronics was applied to the task. Innovative strategies were evolved for deploying sensors. A start was made on providing a theoretical basis for the phenomena of ultrasonics and underwater sound transmission.

Australia's Contribution

Australia contributed little to the technology until after World War II. The War demonstrated the extreme vulnerability of our trade routes to a maritime threat. It made defence planners think actively about the weapons and sensors needed to defend those routes and the vessels plying them from the submarine threat. Awareness of the need corresponded in time with the establishment of the first indigenous defence research capability in Australia.

8 Hackmann, *Seek and Strike—Sonar, Anti-Submarine Warfare and the Royal Navy 1915-54.*

The *Ikara* anti-submarine missile was the first outcome of this conjunction. *Ikara* was designed in response to the widespread deployment in the early 1960s of the so-called 20/20 sonar. This device was reputed to have a range of 20 kiloyards while the ship on which it was mounted travelled at 20 knots. Such fabulous performance made the use of ship-launched depth-charges an inadequate response to the submarine threat. The happy coincidence in 1960 of a Chief of Naval Staff (CNS)[9] and a Chief Defence Scientist (CDS),[10] both of whom had confidence in the ability of Australian infrastructure to design and build a system, saw *Ikara* move from concept to service in the amazing period of only seven years. Several things contributed to this speed of which the most important were:

- the engineering technology base out of the *Malkara* program;
- the almost simultaneous start to work in industry and the Defence Science and Technology Organisation (DSTO);
- the willingness of researchers to undertake directed research;
- the unswerving support of the RAN; and
- the personal authority of the CDS.[11]

Dr Butement also committed the nation to work in the area of sonobuoys. His enthusiasm for the use of spaced explosive charges to ensonify the sea was referred to as making 'passive buoys active'. While never successful in itself it led to attention being given to the use of hydrophone arrays in sonobuoys. After a variety of experimental linear arrays were examined, this work led ultimately to *Barra.*

9 Vice Admiral Sir Henry Burrell, KBE, CB, Royal Australian Navy (Ret'd).

10 Dr Alan Butement, CBE.

11 James W. Crompton, *The Making of a Missile Guidance System*, (Thorn EMI Electronics, Adelaide, 1985), provides a full and fair assessment of the contributions of the RAN, DSTO and Australian industry.

Both the *Ikara* and *Barra* developments involved significant technology transfer between the Australian Government and industry. Largely in response to Australian Government initiatives, industry set up the infrastructure to provide broad national capability in the underwater technology field. This made the management of later programs such as *Mulloka* sonar, the Sonar Acquisition and Display System (*SADS*) and the *Kariwara* Towed Array System possible. It gave industry a much more prominent role in those programs. These later programs established technical mastery of the technology and made the climate ripe for the next major Australian development in the field.

THE LESSONS

As someone once said, those who ignore the lessons of history are condemned to repeat them. What are the lessons that history teaches in respect of underwater technology?

Ideas are easy

Our look back at the early years of the development of sonar technology reveals that the field has never lacked for clever ideas and novel solutions to technical problems. We have noted how the U.S. from virtually a standing start in 1917 was testing towed arrays of hydrophones complete with rudimentary beam-forming electrical processing by October 1918. The inter-war years, even though activity was greatly constrained by lack of resources, saw great progress made on the development of transducers, on the measurement and understanding of the properties of the sea, on the reduction of self-noise and the construction of usable sonar systems.

In Australia, where it might be expected that the national contribution to the technology would be a single product, we have been able to come up with the ideas and initiatives needed for no less than four world class systems—*Ikara, Barra, Mulloka* and the *Kawiwara* towed array.

In every case where underwater technology has been troubled by delay or inadequate performance, lack of ideas was not the cause. The real problem continually manifests itself as a failure to package clever technology in a way that will allow it to survive and operate in the hostile environment of a military mission.

The SC acoustic listening device was widely used in the Allied fleets in 1917 and 1918 but not because its performance was superior to contemporary developments. It was very much inferior to what was being tested concurrently. It was used because it was reliable in Service hands and could be produced quickly and in volume. The first piezoelectric hydrophones failed because they were not waterproof or because they introduced excessive turbulence into their surroundings. Valve amplifiers and electronic processing were not used in Service because they were too unreliable and were too fussy about the supply of power. The sonar dome was only ready for deployment at the beginning of World War II because it had been given priority for development between the wars. The idea was good and was available in 1918. Getting it to a stage where it was useful took a further 15-20 years. (*Ikara* is virtually the sole exception to this rule. Its seven years from concept to deployment are about half the normal gestation period for a military system.)

Although there is no shortage of good ideas, they sometimes have to wait for technology to catch up with them. A study of Australian military projects during World War II showed that 100 per cent of the successful projects had started well before the start of the war.

Importance of Training

Time and time again in the literature about the early days of sonar, reference is made to the demands of training operators to be able to use the available sonar technology competently. Between the two world wars the RN made a major contribution to the development of the technology by incorporating a simulated echo training device into new sonar systems. During World War II, as the U.S. developed more sophisticated sonar systems, their operational use was constrained by the lack of operators. Most U.S. effort during the latter stages of the war went into this training activity rather than into the development of better sonars.

There are lessons for Australia in this fact as we consider the acquisition or development of longer range and more sensitive sonar systems. Increased sensitivity and increased range are not an unmixed blessing. The number of targets in the volume of water being surveyed is proportional to the square of the range of the sonar system. Thus, a commander who is used to ranges of active sonars of around 20 kilometres will be operating in an entirely new ball-game when placed in charge of a passive sonar surveillance system with a potential range of more than 200 kilometres. At best such a system could detect 100 times as many targets.

Without range information, which is difficult to generate from passive systems, the potential for confusion between targets is horrendous. The confusion can be reduced by automatic detection, classification and tracking of targets by computer but for this the commander will require the help of a quantum leap in data processing. The problems in choosing sensible courses of action will be increased rather than decreased by the mass of data which will have to be considered.

Any solution to this information processing and management problem will ultimately reduce to more and better training for operators of the surveillance sonar. The air traffic analogy is useful here. An air traffic control (ATC) operator has a comparable surveillance range to the sonar operator. The difference is that most of the targets are cooperative and enhance their returns in order to be seen. In conflict they stay at home and thereby reduce confusion further. Even so ATC and Air Defence operators require long training and can only work in short spells due to the stress of the work.

Finding the right staff and being able to deploy them in sufficient numbers in response to a contingency is no different from the problems faced by the Allies in World War II.

Infrastructure

We have seen that the first ultrasonic transducers caused problems to both the RN and the USN in supply of materials. Clever technology is no good unless it is assured of support and supply. This begs the question whether there is a viable infrastructure for underwater technology in Australia. We are able to make sensing devices at Plessey. We can assemble and build sonar wet ends as shown in the *Barra, Mulloka* and *Kariwara* programs. We are able to design and build innovative processing systems as shown in the *Mulloka/SADS* post processor and in the replacement Oberon submarine on-board procesor for the 2007 Sonar and the experimental Self Streaming Towed Array Sonar System (*SESTASS*). We can do this cost-effectively too. We can create, implement and apply sophisticated

processing and display algorithms as we are currently showing in the *Undara* program.

We are confident that the infrastructure exists in Australia to sustain the development of new sonar systems. However, that statement is true only as long as we continue to exercise the infrastructure on indigenous development programs. (We will deal with offset work separately.)

The Environment

The strength of so much of the pioneering work on the application of underwater sound was the very practical way in which the tools and systems developed were related to the specific needs of serving personnel. This attitude carried over into the inter-war years as the relevance of oceanic propagation behaviour became better defined and understood. This lesson has not been lost in Australia. A great deal of work has been carried out to characterise regional operational conditions for the RAN.

The credit for demonstrating the maturity of this Australian understanding and capability must go to *Mulloka*. We have seen how *Ikara* was a specific response to an unfilled Service requirement. *Barra* addressed a technical opportunity but was not specifically adapted for Australian conditions. *Mulloka*, by contrast, was designed to satisfy a peculiar phenomenon of Australian operational waters—standard sonars did not operate well in warm shallow waters.

Available sonars in the early 1970s were designed for deep cold-water conditions. Their sonar energy tended to reflect from the thermal interfaces between warm surface water and deeper cold layers. As a result, submarines were able to evade detection by submerging beneath the inversion layer. Standard sonars detected such submarines in a very erratic manner though they were occasionally able to make contact out to a very great range. The higher operational frequency of *Mulloka* was a successful attempt to penetrate the surface inversion layer. A deliberate trade-off was made in which the long range of the standard sonar was swapped for high probability of detection within a limited range to meet peculiar and regionally unique environmental conditions.

The confidence of the Australian designers who were able to accept the risks of this trade-off based on their understanding of their physical environment is surely the best foundation for future underwater technology development in Australia.

Follow through

To illustrate our final point it is instructive to look at the sequence of British sonar systems during the period between 1918 and 1937. In that time the Admiralty tested and commissioned no less than 25 different versions of their standard underwater listening device.[12] Compare that with our Australian experience since we have been actively interested in underwater technology.

Ikara has been described as the product of a lucky conjunction between a CNS and a CDS, both of whom had the will and confidence to back an Australian development. Too often today we seem to be plagued by lack of confidence. We are too eager to export the problems of managing the development of a weapon system and to import 'solutions'. We exhibit too nice a concern for financial accountability in its narrowest sense. According to the key *Ikara* designer—'We seem to be the only nation in the world with a negative NIH (Not Invented Here) factor'.[13]

What are the consequences of this lack of national self-confidence? In each case that we can refer to in the Australian context, *Ikara*, *Barra* and *Mulloka*, a highly successful Australian product went through one single iteration. In none of these cases was any concerted effort made to capitalise on the skill and experience built up by slogging through the prototype, preproduction and Mk1 production phases. The problem of engaging targets detected by modern so-called 20/20 sonars has not been solved in any other fashion. We should be asking where are *Ikara* Mk2, Mk3 and Mk4.

Why has it taken us nearly 12 years to approach the development of an improved *Barra*?

Why are Australia and New Zealand apparently determined to equip the ANZAC ships with an overseas-sourced sonar? At best this is unlikely to have been designed for the specific regional requirements of Australia's operational waters. At worst it could have been designed for a totally inappropriate set of conditions. We have already made the national investment in active sonar technology. We are already up the learning curve in this area. Why should we subsidise another countries research and development at the expense of our own technology base? We already have a good sonar in Australia. It has been designed and built specifically for the environmental conditions that are peculiar to our region of the globe and is just begging for an improvement program. Are we ever going to be allowed to build Mark 2, particularly now that we know exactly what is wrong with Mark 1? (This is more than we are ever likely to know when we purchase somebody else's Mk4 or 5.)

Industry must itself take much of the blame for this state of affairs. It is really very hard indeed to imagine a new US warship being equipped with a foreign-sourced sonar. It is impossible to imagine a new French warship with anything other than a French sonar. It is very easy to imagine the pressure that would be immediately applied to Senators and Congressmen and Members at the prospect. Yet we, that is industry, allowed *Mulloka* to be passed over with hardly a murmur of protest. We have not agitated during those 12 years for a *Barra* cost-cutting program. We have not invested in a *Barra* Mk2 with better performance and improved economy. *Ikara* was allowed to expire without protest.

By the same token our national defence procurement policies make it very easy for industry to live with this state of affairs. Cooperation with an overseas partner on building to print entails relatively low risk. The work is unchallenging but profitable. The overseas partners usually have little incentive to squeeze their Australian partners since this will cut back their Australian industry involvement credits. It must be easier for them to be generous with an Australian firm confident that:

- that way the partner will never develop the efficiency edge to be a competitor; and
- the partner never had access to current technology anyway as the product being built under the AII program was probably designed eight to ten years earlier.

12 Hackmann, *Seek and Strike—Sonar, Anti-Submarine Warfare and the Royal Navy 1915-54*.

13 J. Adams, in conversation with Andrew Gibb.

We do not even get the minimal continuity from our offset work that would help keep our indigenous infrastructure in an oxygen tent. We pose it as a challenge to name an offset program which has led to involvement in follow-on work on later versions of a defence product in the country of the offset principal. In other words, though we helped build MkN for the Australian service, we have never had a role in the design, development and manufacture of MkN+1 for either Australia or the country of origin.

A DIRECTION FOR THE FUTURE

The Threat

The threat to Australia from submarines is low according to the 1987 Defence *White Paper*.[14] Submarines are not, unfortunately, the only threat against which we need the protection of a mature underwater technology industry. This same technology is able to develop defences against surface seagoing threats, against mines, against torpedoes and against other forms of underwater hostile intrusion into our territory and hostile interference with our trade.

Australia is also 'threatened' by a range of non-hostile activities. We are fortunate to occupy an island continent which is so far free of many viruses and diseases endemic elsewhere. We have vested interests in protecting our coastal resources from exploitation by intruders. We are determined to detect and deter illegal incursion by criminal elements. In these cases, also, the use of underwater surveillance technology can improve our capability to protect ourselves from threat.

Strategically placed active and passive underwater sensors can detect the movement of military and civil surface vessels. They can provide some warning of the passage of aircraft in their vicinity. They can be used to seek and interdict manned and unmanned hostile equipment.

Status of Industry

Where exactly does Australian industry now stand in underwater technology? Australians participated in the field almost from its infancy. In the post-World War II period they demanded and got a leading role in the technology with such products as *Ikara*, *Barra*

14 Kim C. Beazley, *The Defence of Australia 1987*, p.38.

and *Mulloka*. This position of technological advantage has not been lost as can be seen from the enthusiasm of overseas companies to get access to programs like *Kariwara*. The care taken by the Department of Defence to protect *Kariwara* with Australian Ownership and Control of Information (AOCI) status confirms this. Defence and Australian industry are now able and experienced enough to undertake the next stages of a program of underwater technical development.

The relevance of any such program needs to be considered in terms of our relations with our regional neighbours. Our needs are in many respects alike. Our maritime trade has this in common with that of our region—it arrives from many directions across the Pacific and Indian Oceans. Adequate knowledge and information about surface and subsurface traffic in those oceans is essential to the defence planning not only of Australia but of all our adjacent neighbours. We have referred already to the problems we anticipate in managing the volume of data expected from underwater surveillance systems now in development. Cooperation with regional partners can assist us greatly in reducing this volume of data so that we can concentrate on those activities which threaten our national and regional self-interest. Industry sees no need to be secretive about the results of this surveillance. Indeed, we see excellent commercial opportunities in the sharing of both surveillance capability and surveillance data with our neighbours and trading partners.

There are some obstacles to be overcome before we can view the future with confidence.

Consolidation of National Resources

At present Australian resources to address underwater technology reside in several organisations. Industry has attempted to get organised and to present a stable and consistent response to the technology and build a large national resource in underwater technology. This is necessary so that there is a body outside the government which is sufficiently large and resourceful to be a responsible, long-term custodian of the technology base in underwater technology. These attempts can be easily frustrated by procurement policies that seem to overlook national capability.

Given our national state of readiness, it is necessary to ask why so little advantage has been made of it in the context of the

ANZAC Ship Project. It is not sufficient to point to offset work to answer this question, even though that offset work will keep large sections of industry at work in the technical area of underwater systems engineering. Look at the offsets work from our point of view.

Industry has no option but to cooperate with overseas suppliers of defence equipment looking for AII partners. We have the choice of cooperation or no work. It is hard, however, to be enthusiastic for the technology transfer associated with 'build to print' manufacture of obsolescent technology. Such work rarely includes opportunities for industry to participate in development.

This point is worth stressing. Cooperative development with overseas companies should never be tied to current procurement activities. It is already too late. The current procurement should be used as a lever to negotiate participation in future programs. Developments with overseas companies are best initiated at the conceptual design stage, with equal rights for both parties to exploit the ultimate product. This avoids the situation that often occurs in offset contracts. The Australian company ends up with little or no effective advance in technology and with no product rights which can be exploited. Worse still, the Australian company has usually had to apply its best engineering effort to the program and this is then unavailable for indigenous research or development.

A good case can be made that the development of indigenous designs and products, even if these are no better than potential imports, is a better vehicle for building skill and knowledge than any amount of offset manufacture. It is only by carrying out the detailed design of a series of related products over a long continuous period that the necessary skills and experience are entrenched in the technology base. We will have more to say on this topic when considering the role and attitude of government bodies to industry participation in research.

Given this perception of national opportunities lost it is frustrating to see those same overseas firms setting up in Australia to exploit indigenous capability. We have in Australia something that is worth fostering and encouraging. Australian industry is doing its best to rationalise and entrench our underwater technology capability. The necessary consequence will appear to be a reduction of internal competition. Encouragement of overseas bodies to supply apparent

competition will not necessarily be for the good of the industry in Australia.

Finally, if we see potential for regional cooperation in the area of underwater technology, we believe that this should be on the basis of regional solutions to regional requirements. These are very different from the requirements for NATO and North Atlantic conditions. They will not be satisfied in Australia or in the region by allowing this country to be used as an uninvolved platform and convenience for the marketing of NATO technology to our own region.

Technology Transfer and Research

DSTO is a traditional custodian of the technology base and has in the past shown initiative in cooperation with industry and transfer of technology. Australian industry is watching with interest the changes in DSTO as a result of the 1987 reorganisation. We believe that these changes have the potential to affect the relevance of DSTO work adversely. We see that they will redefine the interfaces between DSTO and the armed services and between DSTO and industry. We hope that the new arrangements will be superior or equal to the old ones but the results are not yet apparent.

The emphasis of the changes in shifting the span of DSTO attention from tactical to strategic timeframes is of concern. It is almost certain to cause a hiatus in the DSTO/industry nexus and industry may have to address medium-term Service needs without the support of DSTO. We believe that we have little to fear from DSTO as a competitor under its commercialisation thrust, though we have some concern that the rewards of commercialisation are being sought without acceptance of the responsibilities of self-sufficiency.

Our experience is that research is of no value (apart from any personal kudos that may accrue to the researcher) unless it is firmly anchored to the processes of technology transfer. The successful transfer of technology demands excellent experimental record-keeping, meticulous attention to design disclosure and first-rate documentation in general on the part of the transmitting organisation. The skills in question have been seen as skills that are less appropriate to the 'research worker'. Too often these requirements are compromised by the need of a research worker to be the first to publish novel aspects of research work. Unfortunately, formal publication in a learned journal does not satisfy industry's need for documentation. If formal publication is treated as the only or most important objective for research workers, technology transfer is put at risk. We are concerned that the DSTO changes will devalue documentation skills further as emphasis is placed on individual excellence and originality at the expense of discipline and team work.

Technology transfer places its obligations on the recipient of the transfer also. It is probably right that industry should accept criticism from within DSTO that it has in the past been too passive in playing its part in the process. Industry must and will undertake more of its own internally funded research for two reasons. The first is for the immediate benefits of such research in terms of new products and processes. The second is that it leads to better comprehension by industry of the needs of government sector research organisations when they engage in transfer of technology.

Breadth of Vision

Research and the opportunity to develop reflective and creative skills are expensive to fund. As someone once remarked, 'It's hard to see that the swamp needs draining when you are up to your neck in alligators'. Until recently, defence industry has lead a hand-to-mouth existence with little spare resource to put into research. The logistics of entering a competition for even the least profitable contracts are daunting. Bid preparation is an expensive business. A common estimate of the success rate for Australian tenders in the defence field is no more than one in ten. This can erode the profitability and drain the will of a company to lift its vision to the point where it can see beyond the next tender.

Signs that competition for competitions sake is abating are very welcome. Industry believes that it adopts an ethical approach to its relations with the Department of Defence and does believe in giving a fair days work for a fair days pay. We are disappointed when having given more than that in a risky development activity we see contracts go to cheaper tenders submitted by firms which do not understand the risks of the program and have not shared in the risks of development. It is even more frustrating when we subsequently hear of such contracts being driven up in cost by engineering changes that were anticipated and absorbed in our cost structure.

Continuity

In discussing the inter-war developments in ASDIC we pointed out that the basic RN sonar set went through over twenty revisions and improvements in that period. This level of volatility in an important piece of military kit should not be surprising. It reflects a concern on the part of the developers and the users to keep at it until a fully satisfactory level of performance is reached.

It is more concerning that it is hard to think of an Australian development or an Australian offset program that has reached the stage of having a first iteration let alone a twenty-first. The *Ikara, Barra* and *Mulloka* experiences are all symptomatic.

Our experience in owning foreign-sourced defence material has not been used either. It is almost a truism that if we buy an item of capital equipment from one company or country we will replace it in due course with equipment from a different company or country. It is as though we are determined as a nation to prove that familiarity breeds contempt. We only seem to learn enough about the weapons systems in inventory to resolve to avoid them and their problems in future.

There is no perfect weapons system. They are all vulnerable to counters and to the progress of the technology. Their use in service in peacetime is designed among other things to identify these shortcomings and to develop fixes for them. Such fixes would normally be designed into later versions of the system. Instead of abandoning a line of development because it is deficient in some respects, we should learn from the deficiencies of current systems so that we can participate in their improvement. We should by now be sufficiently mature as a nation to accept that no product will ever perfectly satisfy our needs. Ownership of complex defence equipment and systems demands a continuing commitment to management of that system and planned development of it as our understanding of its capabilities and our needs evolve through use.

New Initiatives

Australian industry in its corporate planning for further investment in underwater technology attempts to identify defence needs and development opportunities. The obvious target for the next five years is the Australian Surface Ship Towed Array Surveillance

System (ASSTASS).[15] Indeed, if a company were to adopt a purely reactive attitude to defence initiatives, ASSTASS would be the only objective in sight. Australian industry is keen to participate in ASSTASS and believes that it has a special contribution to make, in particular towards the ASSTASS system design process. Industry is however equally determined to create opportunities in underwater technology. We can identify certain areas of technical research and development for the investment of resources. Ultimately, rather than relying on Defence initiatives, we would expect that industry would be able to make unsolicited proposals to the RAN and to market resulting products in our regional export markets.

Technical areas for research by industry include the following programs:

- digital-signal processing architecture;
- data management schemes for sonar applications;
- signal processing software development;
- surveillance spin-off applications;
- fibre-optic sensors; and
- high power, low frequency transducers.

While the prosecution of these initiatives is within the control of any one company or section of industry and can be managed and serviced by that company, we are acutely aware that we operate within a larger national context. Within that context there exist problems that are beyond our scope to solve alone. In what follows we will attempt to identify those problem areas and to propose a mechanism for addressing them on a national basis.

It is instructive to look at some of the underwater technology initiatives that are apparent but are clearly beyond the present capacity of Australian industry to address. We see a need for at least feasibility studies into some of the following concepts. These studies could be carried out quite economically by industry. They would help to refine

15 D. Foxwell, 'Silence is Golden: Passive Towed-Array Sonar Programmes', *Military Technology*, (Vol.XII, Issue 8), 1988, pp. 54-60.

the national posture on underwater technology and concentrate national effort into the most productive channels. Areas that need investigation include:

- the role of moored arrays in guarding choke points (this could build on RAN Research Laboratories work of the 1950s and 1960s which is presently dormant);
- C^3I and the integration of underwater surveillance data with the output from other sensors and sources of intelligence such as over-the-horizon radar;
- development of low frequency, high power sonars for fixed and shore-based installations; and
- mine warfare and the place of high resolution systems such as synthetic aperture and side-scan sonar.

An Offer from Industry

As recognised by the 1987 Defence *White Paper*,[16] Australia and its regional partners will have to retain an interest in underwater technology for a long time. We are trading nations with high bulk products to sell. Our trade is therefore very dependent on our maritime links with the rest of the world. We are particularly vulnerable to threats of a maritime offensive against that trade. We should prepare for those threats in a planned and comprehensive way using all our regional resources for the task in a managed cooperative fashion.

Just as the automotive industry required government leadership and clear policy direction to undertake its restructuring with confidence, so the national underwater technology industry, on a smaller scale, requires an equally clear statement of strategy and objectives. Industry is very ready to contribute to the development of such a strategy.

Opportunities for underwater technology development leading to innovative products for defence and industrial application are available. They are suitable as vehicles for export drives. They will not be developed by the Government-funded research organisations because they do not closely match their research

16 Kim C. Beazley, *The Defence of Australia 1987*, p.7.

needs—originality and publishability. They will not be developed by a fragmented Australian industry with large sections under foreign control and ownership. They may be developed in response to long term undertakings from Government to either procure them for its own use or (and this amounts to a very similar thing) to support them in an export drive.

A strategy to exploit these opportunities should address such factors as:

- Future requirements for sensors, processing systems, display systems, data management and communication systems for handling information derived from beneath our regional water resources.
- The development and deployment of the national or regional skill base in underwater technology, including the division between government and industrial research, recruitment and training of scientists, engineers and technicians and their application to the defined future requirement.
- The development of a business plan that would bring the cost of the current fragmented national research effort under control, would encourage regional interdependence and would reduce the import bill for technology and products in this area.
- The assignment of priorities for effort in more detail than has so far been given in the *White Paper* and taking into account the commercial potential of innovations in areas outside defence.

Australian industry will support any initiative to develop such a strategy and is ready to participate in discussions with all concerned bodies aimed at formulating a national plan for the medium and long term future.

CHAPTER 11

NEW SOFTWARE ENGINEERING TECHNOLOGIES

Andrew Johnson

The countries in our region are in many ways very similar, but in others very different. The peoples, cultures, state of technical development and ratios of resources to population in our countries are as diverse as in any part of the world.

Common factors include the requirement to provide value-added processing to the exploitation of raw materials, a large supply of energetic and, in many cases, very well educated people and the ever present need to resist moves by the advanced industrial nations to swamp the developing technology of the region.

The acquisition and effective use of the latest technologies will play a vital role in our region's success. Technology and the economic growth it brings will also help enhance the security of our region. Software that controls the operations of digital computers is at the forefront of the new technologies that have emerged during the last four decades.

In this chapter I will explain what is meant by software engineering and examine its history and current status. I will also provide statistics showing the size of the worldwide and Australian software markets. Other sections of the chapter will deal with the relevance of software engineering to Australia, the export markets that exist for Australian companies and the potential for regional cooperation in this field. Finally, I will make a few predictions regarding the future of software engineering.

WHAT IS SOFTWARE ENGINEERING?

The term software engineering is often used fairly loosely by engineers and data processing practitioners. It is a complex concept. Therefore, I will first define it rigorously and then explain what a software engineer does. Typically, the term is employed to contrast it with the 'arts and crafts' approaches that have characterised a great deal of software development.

The following definitions are given by Boehm:

> Software is the entire set of programs, procedures and related documentation associated with a system and especially a computer system. Engineering is the application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to mankind in structure, machines, products, systems and processes. Software engineering is the application of science and mathematics by which the capabilities of computer equipment are made useful to mankind via computer programs, procedures and associated documentation.[1]

Implicit in these definitions is that the application of science and mathematics includes the traditional engineering concerns of reliable, predictable management of development activities. Again, if we look at Webster's Dictionary, we find an engineer defined as 'a person who skilfully manages a project' and engineering as 'the management of an intricate enterprise'.

Now let me turn to what a software engineer actually does. While individual circumstances produce many variations, there are several basic activities that must be addressed in any major software development undertaken under the disciplines which today are accepted as competent software engineering.

The basic stages are:

- *Requirements analysis and definition*: The functions, goals and constraints of the system are established in consultation with the system users. They are then defined in a rigorous and complete statement, understandable to users and development staff. Concurrent with the growth of software engineering

1 B. Boehm, *Software Engineering Economics*, (Prentice Hall, Englewood Cliffs, New Jersey, 1981).

was the recognition that the stages of a software development project constitute a predictable life cycle. Originally proposed by Royce[2], the so-called waterfall life cycle model (Figure l) is essentially similar to that of any complex product development.

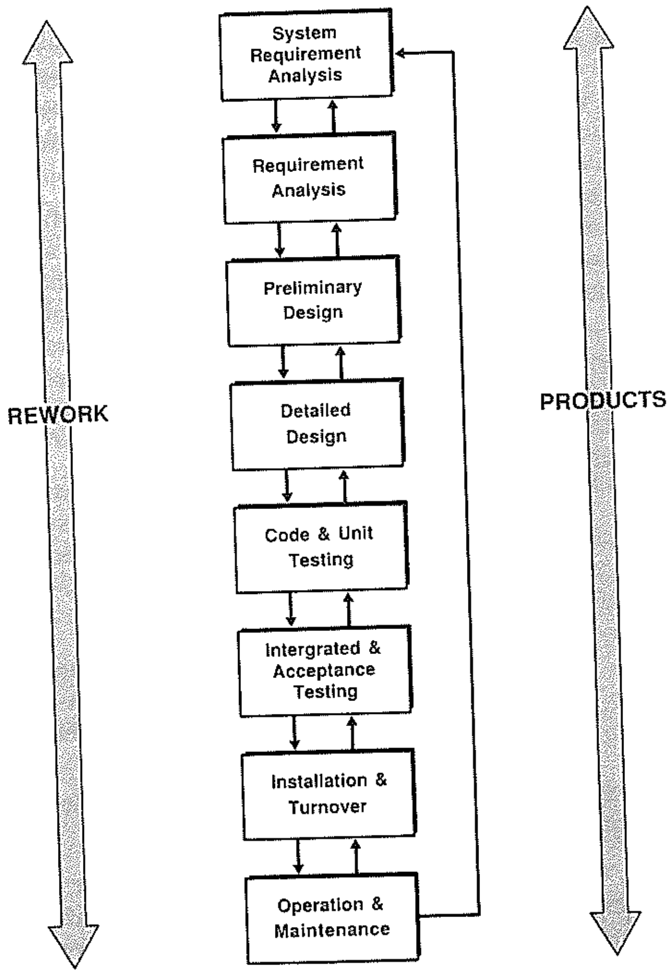
- *System and software design*: With the requirements definition as a base, functions are allocated to hardware and software subsystems. These functions are further broken down into structures of components for which software or hardware may be purchased or constructed.
- *Implementation and unit testing*. The components of the system are independently constructed and tested against the specifications developed for them during the design stage. The implementation segment, which is the actual computer programming, represents only about 20 per cent of the total time taken for a software project. Programming is thus a relatively minor element of software engineering.
- *Integration and system testing*: Individual components are integrated and tested as a complete system. At this level, testing is based on the requirements definition rather than design specifications.
- *Installation and maintenance*: The tested system is installed and operated in the role defined by user requirements. Maintenance activities comprise correction of faults and enhancements of the system to support new requirements.

The concept of the software development life cycle illustrates two important features of software engineering.

First, there is no mass production activity similar to that for most engineered products. In a sense, the final specification for software is the product. Therefore, if we are to compare software

2 W.W. Royce, *Managing the Development of Large Software Systems: Concepts and Techniques*, (Proceedings of WESCON [An annual computer conference co-sponsored by IEEE], 1970).

FIGURE 1
SOFTWARE LIFE CYCLE ACTIVITIES



Credit: W.W. Royce, 1970

engineering with other branches of engineering we must bear in mind this one-off or custom-built characteristic.

Second, we notice that software engineering forms an integral part of an overall systems engineering activity. Figure 2 shows the part that software development plays in a complete system development; that is, as a subsidiary element to systems engineering and as a parallel analogous path to hardware engineering. The dividing line between system and software engineering is often unclear. However, there is much more to software engineering than programming and full awareness of the total system functionality required is a major key to success. In addition, the software engineer needs to be able to understand and take account in their design, the system requirements for:

- responsiveness;
- reliability;
- human factors; and
- ability to operate under conditions of hardware degradation.

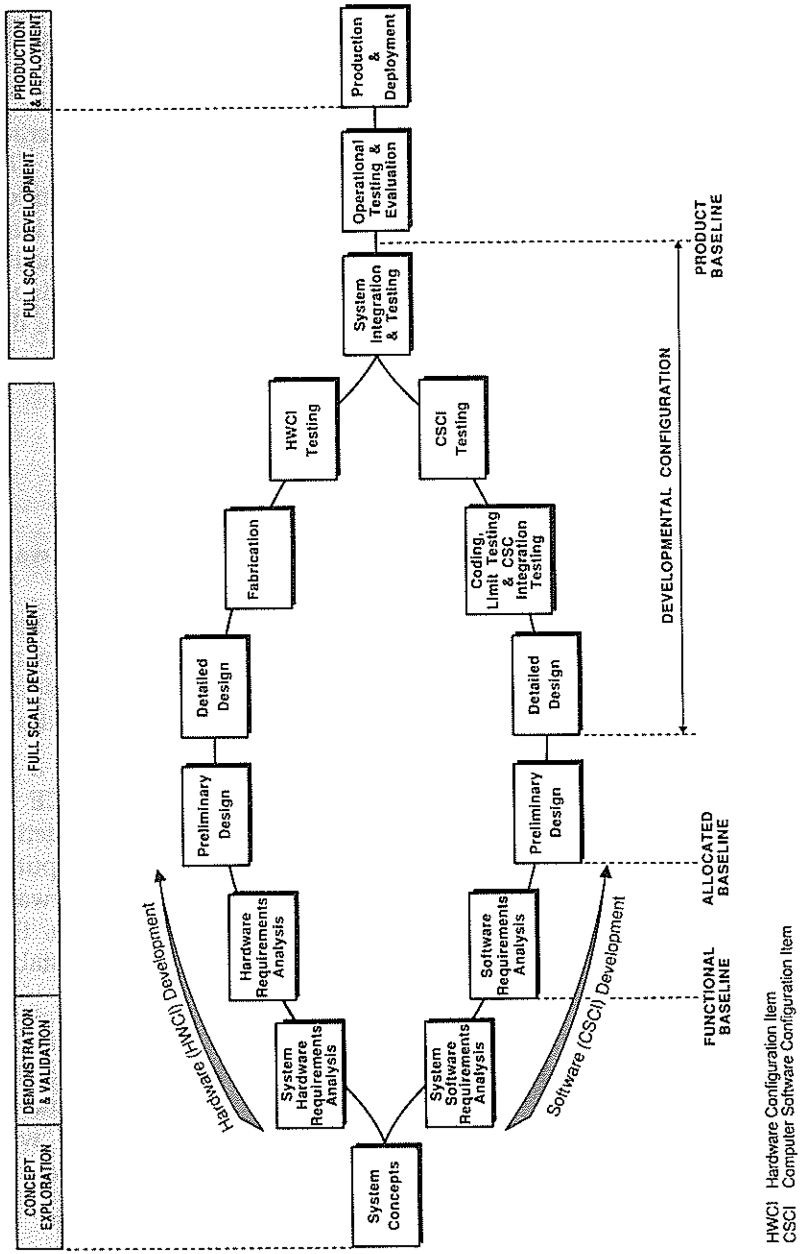
Finally, these definitions apply generally only to the development of large-scale systems. As in any profession, many aspects of the work are not apparent in similar projects and some activities or responsibilities can be omitted or amalgamated without difficulty.

SHORT HISTORY OF SOFTWARE DEVELOPMENT PRACTICE

Any review of the history of software development practice must first remark on its brevity. Development of digital computer programs has been a reality for perhaps forty years. Software engineering, as a practice, is maybe fifteen years old. Hence, the history we observe is that of a new discipline emerging, not of a stable technology becoming progressively refined.

In the 1950s, when large-scale development was in its infancy, construction of computer-based systems was dominated by, typically, electrical and mechanical engineering issues. Software requirements were, by default, to make up the difference between what was required and what could be done by hardware. Where the software

FIGURE 2
THE SYSTEM DEVELOPMENT CYCLE



required was small and simple, this approach was reasonably successful. However, as time passed, more and more projects failed to deliver usable systems within reasonable time and cost constraints.

With hindsight, two major factors can be identified as contributors to these failed projects. First, the scope and complexity of the software being developed had increased substantially. Ad hoc development approaches which had been successful with smaller programs failed to cope with more complex applications and the problems of integrating software built by large teams.

Second, the computing hardware in use had become a production item, rather than special purpose, perhaps 'one-off' equipment, as in earlier projects. Computing system development was no longer primarily a hardware development exercise, and the methods and management structure of an engineering project were no longer automatically present. Control of overall system development passed into the hands of programming or application area specialists, with predictably mixed results.

By the end of the 1960s software development had reached a crisis point. Development projects were characterised as disorganised, unreliable and likely to produce overruns in both schedule and cost. The major emphasis had become program development rather than systems development. Established principles of quality assurance, configuration management and so on were not formally or predictably applied. The systems produced were poorly documented and performed unreliably, with consequent effect on maintenance costs. From a management viewpoint, the projects were difficult to control due to poor visibility and predictability of the development process itself.

It was concern for these factors, in relation to operationally critical software, which led NATO to sponsor landmark conferences on software engineering in 1968 and again in 1969. However, the term 'software engineering' was coined not to recognise a new approach but rather in the hope that it would draw attention to the need for greater discipline.

In the intervening years, significant progress has been made in establishing the mathematical and scientific bases for software development. Computing systems development practice varies significantly with the size of individual projects and the application area to which they are addressed. It is probable that there will always be some level of development work undertaken by ad hoc methods, typically that involving small systems. However, the trend is strongly toward more formalised approaches.

THE STATE OF THE ART

Worldwide

The methods of computing system development have thus undergone a maturing process, which is well described by Ward and Mellor.[3] They characterise early system development efforts as implementation dominated, with the major concerns being what was feasible within the constraints of hardware and software technology. Current system development, by contrast, is problem dominated, with the assumption that technology will support at least one solution to most problems. As a result, the system developer is no longer concerned primarily with hardware or software. Rather, the development activity must focus on accurately describing requirements and then managing the development activity to an efficient and effective conclusion.

However, the level of maturity reached varies with the area of application. In specific or constrained application fields, such as computer-aided design systems for engineering, or management information systems for business, most progress has been possible. In such areas, use of software packages, re-use of software components, automation of the programming task and systems programmable, or modifiable, by end users are to be seen.

By comparison, the flexibility and scope required of more general development projects, such as those for real-time and embedded systems, have proved more difficult to address. The same trends are evident, however, and we are clearly in a section of the learning curve where significant progress can be made.

The use of computer-aided software engineering (CASE) environments, typically comprising high resolution workstations running an integrated set of software development tools, has become a

3 P.T. Ward and S.J. Mellor, *Structured Development for Real-Time Systems*, (Yourdon Press, Prentice-Hall, New Jersey, 1985).

hallmark of the software engineering professional. Automatic code generation for general applications makes slow but perceptible progress while techniques for re-use of software components continue to improve.

However, our aspirations for software engineering must recognise the essential difficulty of the projects attempted. Brooks asserts that the essence of modern software systems comprises complexity, conformity, changeability and invisibility.[4] All these factors complicate the software engineer's task.

Complexity

Software entities are more complex for their size than perhaps any other human construct; worse, the complexity increases non-linearly with size. In this respect they are unlike computer hardware, for example, where size implies replication of elements, with little increase in complexity. Figure 3 shows the demand for increasingly complex software systems growing exponentially for a sample application area. Thus, as our skills in developing major systems increase, the complexity of the task that we are faced with grows as fast if not faster.

Conformity

In respect of conformity, software must meet the arbitrary requirements and interfaces dictated by its place in the overall system. In many cases, the software is seen as the most easily conformable element and thus must resolve the most difficult interfacing and coordination issues.

Changeability

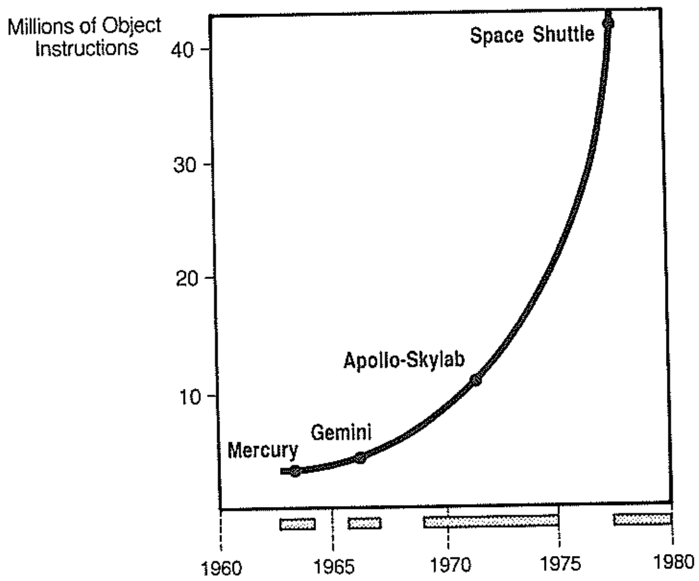
Software is also seen to be easily adaptable and is expected to accommodate a level of change that would not be contemplated for hardware elements.

4 F.P. Brooks, 'No Silver Bullet—Essence and Accidents of Software Engineering', *IEEE Computer*, (Vol.20, No.4), April 1987, pp.10-19.

Invisibility

Finally, software is invisible, inherently not embedded in space. As a result, graphic representations such as plans and scale models are not naturally available to assist the software engineer.

FIGURE 3
GROWTH IN DEMAND FOR MANNED SPACEFLIGHT SOFTWARE



Multiple representations, each capturing some aspect of the software, are the best techniques currently available. As a result, some of the more powerful techniques of our minds cannot be directly applied to software.

State of the Art in Australia

As in the rest of the world, the standard of software development practice in Australia varies considerably. However, significant access to overseas methods has resulted from Australians gaining work experience abroad, by the visits of consultants and

educators to Australia and by projects being carried out jointly by Australian and overseas firms.

As a result, the best Australian practice is of world class, as evidenced by the level of Australian standards for software development and quality management systems, AS3563 and AS1821. (The latter is currently being changed to the AS3900 series).

Indeed, our position in the world community is such that we are able to draw on the experience of both European and American practices to our benefit. Similarly, although our local market limits the size and frequency of systems development opportunities, it results in some benefits.

Australian industry has of necessity become more flexible and adaptable than it otherwise might, both in terms of development methods and system application areas.

The development of the computing systems engineering industry in Australia has largely followed the same pattern as overseas industry. However, the historical dominance of the hardware manufacturers did not occur locally. Overseas the large-scale hardware system development projects that contained early software development efforts were typically funded by hardware manufacturers or Defence agencies.

In Australia, projects of such scale were not undertaken and Australian industry has never been a volume provider of hardware for computing systems. As a result the local system engineering activity has always been software dominated.

Australian computing system developers have, from the early days of the industry, developed systems based on overseas supplied hardware and software packages. The locally developed software has tailored the system to local requirements, integrated components from various suppliers and supported evolution of system capability.

Defence industry projects provide a good example of the evolution of local capabilities. Early projects were limited to modification and integration of overseas-supplied systems. The ground support and airborne systems developed for the RAAF long-range maritime patrol aircraft are typical, involving integration of systems hardware and software from U.S. and U.K. defence suppliers.

As local industry capability has developed, projects have become significantly more complex, requiring much greater original engineering development. Current projects include, for example, development of combat systems and shore facilities for the new RAN submarines. Here, a project team of over 100 staff is developing systems to substantially extend the capabilities of jointly developed overseas hardware and software.

Again, the *Jindalee* over-the-horizon radar development for the RAAF involves production of systems based on basic research and prototype systems produced by Australian defence scientists. The Federal Government is now (November 1989) evaluating tenders for the next phase of this project in which a network of such radars will be developed. One of the conditions of the tender, which will be worth several hundred million dollars, is that an Australian company is the prime contractor, demonstrating the maturing of Australian industry to the point where very major system developments can be undertaken in this country.

SIZE OF THE BUSINESS

Worldwide

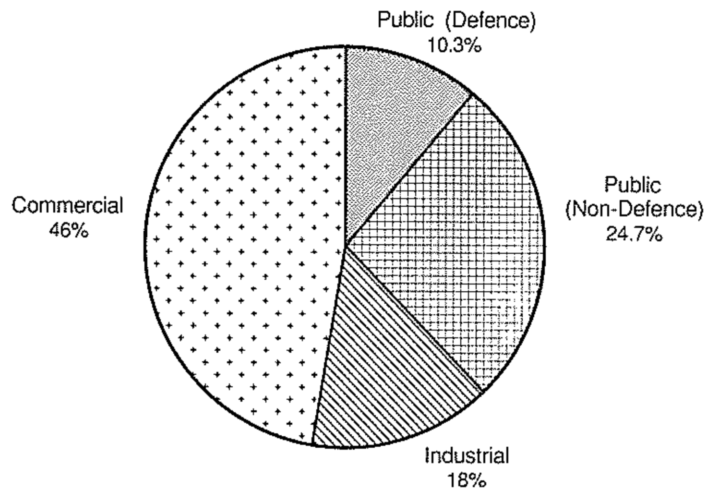
The following statistics and projections were produced recently by International Data Corporation (IDC), the world's leading provider of statistics in the information technology industry, or derived from a report on the Australian software industry from the Australian Industry and Technology Council.[5]

Worldwide sales of application software amounted last year to over $A42 billion. This market distribution, as shown in Figure 4, is as follows. The commercial market, which includes finance, distribution and services, accounted for $19.4 billion or 46 per cent of the total. Next largest was the public sector which generated revenues of $A15.1 billion or 35 per cent. Of this amount 29 per cent or $4.3 billion was spent on military software. The industrial sector, which takes in manufacturing, mining, construction and engineering, accounted for 18 per cent or $7.6 billion.

5 *The Australian Software Industry: A Report to the Australian Industry and Technology Council*, (Australian Government Publishing Service, Canberra, 1987).

Latest projections show that the worldwide software market is expected to grow at a little more than 19 per cent a year over the next five years to approximately $A102 billion. The commercial market will grow at an annual rate of 19 per cent, the public sector at 21 per cent, and the industrial sector at 18 per cent.

FIGURE 4
WORLDWIDE SOFTWARE MARKET REVENUES
($42.4 billion), 1988.



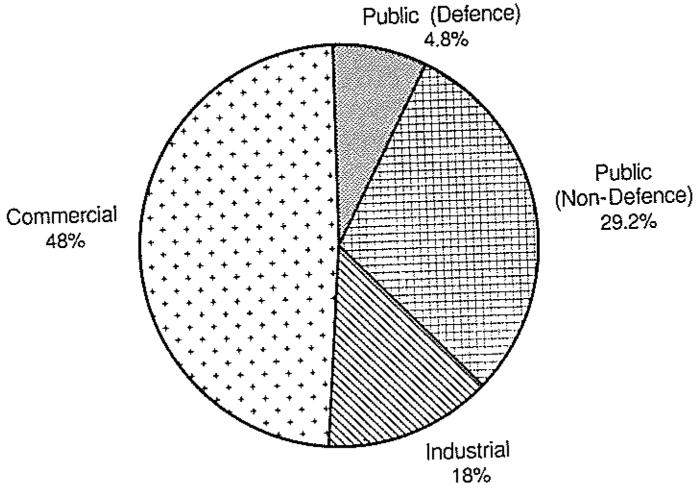
Australia

In Australia the percentage breakdown is remarkably similar. Figure 5 shows the Australian software market distribution.

Of a market generating revenues last year of $846 million, the commercial sector accounted for $402 million or 48 per cent, the public sector $289 million or 34 per cent, and the industrial sector $152 million or 18 per cent. The market for Defence software in Australia has also grown very rapidly in the past five years. In 1984 revenues were valued at $10.2 million while in 1989 they are expected to top $41 million, an increase of approximately 33 per cent a year.

In 1988 the software business employed 16,000 people in Australia. Of this number close to 3.5 per cent worked on Defence

FIGURE 5
AUSTRALIAN SOFTWARE MARKET REVENUES
($846.2 million), 1988.



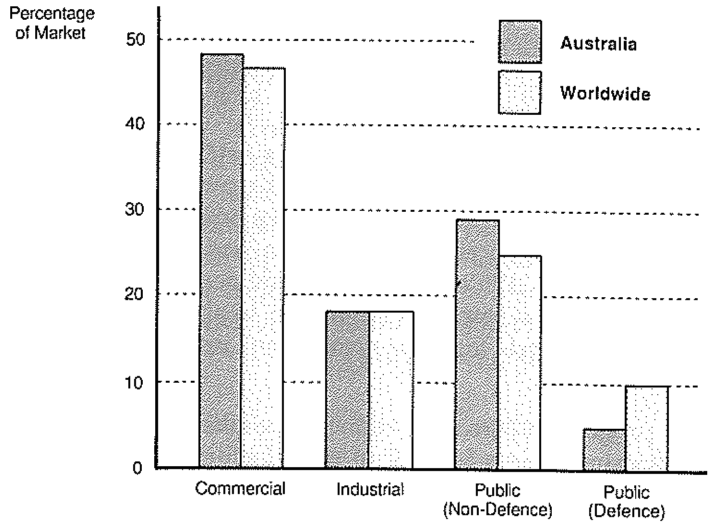
systems. Employment in the industry exhibits both rapid growth and fragmentation into small units. As evidence of this, independent software firms, estimated to number only 100 in 1974, grew from 400 in 1978 to 1200 by 1987. Figure 6 provides a comparison between the relative distributions of the worldwide and Australian marketplaces. In Australia the majority of software engineers employed on defence projects are located in Sydney in NSW and Adelaide in South Australia. Adelaide has become popular for three reasons.

First, the key laboratories of the Defence Science and Technology Organisation (DSTO) which conducts original research into a wide range of Defence related areas are located there. The transfer by DSTO to industry of ideas and technology has provided a sound base for the development of world class products and systems.

The second reason is that there is an availability of talented people created by the development over many years of defence-related businesses in the State.

Third, the South Australian Government has created and fostered a very positive climate for the establishment and growth of defence-related industries.

FIGURE 6
COMPARISON OF AUSTRALIA vs THE WORLD SOFTWARE MARKET DISTRIBUTION



Education Challenge

The software market is expected to grow at the rate of 21 per cent a year over the next four years to be worth $A2.1 billion in 1993, with the strongest expansion being projected for the public sector.

The major inhibitor of this growth is a scarcity of people with tertiary qualifications in engineering or computer science. Each year many thousands of students who wished to undertake tertiary education were unable to gain places in Australian universities. For example, in 1988 300 applicants had first and second preferences for the University of New South Wales Computer Engineering Degree. The course had less than 50 places. Similarly, for the Cooperative Education Program which includes courses in computer science, business and engineering, there were 1,300 applicants for the 200 places. Compare this situation with Singapore which has recognised that software development will play a key role in the country's growth plans. In 1980 Singapore had only 800 computer professionals. Four years later the number had grown to 4,000 and by 1990 it is projected to be closer to 8,000. These computer professionals will be mainly graduates from Singapore's newly established training institutes.

Changes will need to be made by Government and industry so that Australia can ensure that the number of skilled people entering the workforce grows at a similar rate. Certainly, as a national priority, we need to make education in technology and computer science more readily and more widely available.

The Federal Government's *Partnership for Development Program* is one avenue that is helping to alleviate the problem. Under this program, overseas-based companies operating in Australia agreed to export products and services from Australia and carry out research and development here. While the actual implementation of the policy differs for the individual companies involved, in all cases this program will provide a catalyst for the growth of information industry companies in Australia.

The program is already producing results. For example, the computer company Unisys has begun manufacturing laser printers at its plant in Brisbane. Unisys forecasts that exports of these printers will be worth $12 million a year. Similarly, Digital Equipment Corporation (DEC) has signed an agreement with the Australian manufacturing company which will be exported to Digital plants and built into the company's computers and other equipment.

RELEVANCE OF SOFTWARE ENGINEERING TO AUSTRALIA

A report to the Australian Industry and Technology Council on the Australian software industry contains the following statement on the relevance of the software industry to Australia:

> ...the industry embodies many of the activities we wish to encourage in Australian industry and commerce:
>
> — it is a high skilled activity
>
> — it is R&D intensive and provides opportunities for product development
>
> — it can become more internationally competitive without the need for barrier assistance
>
> — and it provides the opportunity for small, innovative business to grow.
>
> More important, however, are the implications for industry as a whole. Software is a crucial component in the competitiveness of the manufacturing and service industries. Increasingly the knowledge, experience and skills which make up a firm's competitive advantage are being expressed as, and encapsulated into, software. Australia's immediate and future trading performance depends importantly on the combination of the country's ability to compete in world markets for products and services based on information technology in general and software in particular, and on the rapid, widespread and effective application of such products and services by industry.[6]

I regard this as an excellent summary of the situation.

Strategic Need

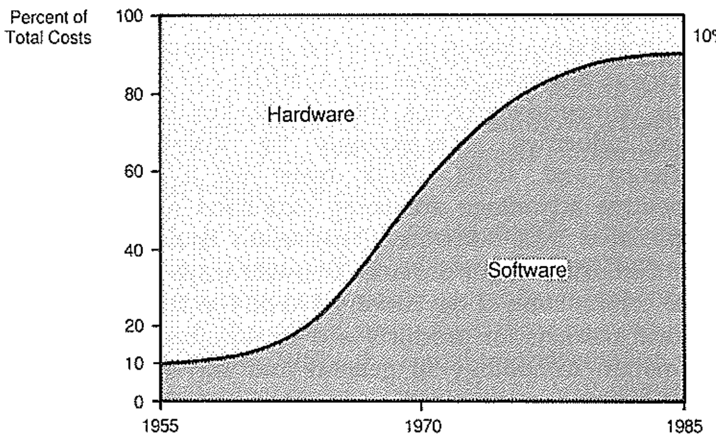
Australia cannot afford to exist without its own independent software engineering capability. As is shown by Figure 7, cost trends for the development of complex systems is increasingly being biased towards the software side.

Software engineers enable the Australian Defence Force to maintain existing systems and undertake enhancements necessary to maintain their effectiveness during their service life. Equally, software is essential for the cost-effective adaptation of overseas-developed defence systems to local needs.

The production of hybrid systems, drawing elements from local and overseas suppliers, has been a successful approach to Australian defence system procurement. Adaptation of special purpose equipment into a multi-role system has also proved effective in

6 *Ibid.*, p.5.

FIGURE 7
HARDWARE/SOFTWARE COST TRENDS



addressing local needs. In both cases the ability to flexibly re-engineer system software has been the key to successful adaptation.

Australian Usage of Products

As the above Figures show, most of Australia's locally produced software is used in commercial applications. However, as manufacturers incorporate an ever increasing number of micro and minicomputers into hardware products destined for the defence marketplace, it takes on greater importance. In fact, in many cases it is the software which provides the sophisticated performance of today's defence products.

Systems that are software rather than hardware based can be precisely tailored to the needs of individual customers. Two countries may order and install the same hardware product but the imagination and skills of the company providing software enhancements are able to make that hardware perform quite differently.

Such changes may be required by a customer for strategic, tactical, geographic, or economic reasons. Alternatively, the hardware manufacturer may be able to meet the specifications for tenders in some cases by changing the performance of the system through software modifications. Another benefit of software based systems is through-life flexibility. By upgrading the software element the user is able to improve the performance and reliability of the system.

Many of today's defence systems are modular in design and construction. When a module is modified, upgraded or even replaced, the effect may ripple through the entire system. This ripple effect can be very expensive in terms of time and money if it demands extensive changes to hardware systems.

To counter this effect, modern defence systems are opting for a greater software content so that a change in one module can be more easily accommodated in associated modules or systems. However, there are certain pre-conditions that engineers and the user need to fulfil before this statement is necessarily correct.

First, engineers should ensure that their design is flexible enough to accommodate changes, additions and upgrades. They must also structure and document the system so that it is quickly and easily understood by other people.

To achieve these results, the use of CASE systems or programmer support environments are becoming a necessity, especially in the development of large, complex systems. In fact, the day is fast approaching when software houses will be unable to implement such systems without the use of modern, sophisticated, development environments.

Another important factor that has helped to build the Australian industry to the point where it is a major force in the development of defence and commercial software is the excellent industrial relations record it enjoys. To my knowledge, there has never been a strike, lock out, stop-work meeting or dispute of any consequence between software engineers and their employers. This harmonious relationship shows every sign of continuing.

POTENTIAL ASIA-PACIFIC REGIONAL COOPERATION

Australian defence companies have forged close relationships with many overseas organisations. Until now these relationships have been with companies based in the U.S. and Europe.

For example, work associated with the combat and ship management systems for the Royal Australian Navy's new submarines is being carried out in Australia in conjunction with U.S., French and Swedish companies. The command and control systems for the Navy's new frigates will be developed in Australia and New Zealand with a Swedish company, while teams bidding for the *Jindalee* Operational Radar Network contract include either U.S. or British companies.

In the past, Australian industry has achieved only limited collaboration with companies in the local region. However, I believe that many opportunities exist for cooperation in defence and industrial systems, such as air traffic control, with locally developed software playing a large part. Such collaboration could be instrumental in enhancing the security of our region. And software-based systems could play a vital role in improving the strength, depth and effectiveness of our regional defence systems. This is particularly relevant in the area of surveillance. Australian defence forces will be aware of the presence of ships, planes and submarines well before they approach the country's coastline.

Signals gathered by over-the-horizon radars, hydrophones towed by naval vessels and equipment in reconnaissance aircraft are, for example, processed by highly sophisticated software systems. None of these defence systems would have been possible without the involvement of software engineers in their design and implementation.

In developing our high technology industries in an increasingly competitive world, we need to recognise the inherent risks and costs involved in achieving this goal. International collaboration is therefore an appropriate approach. It is a sensible means of sharing risks, spreading costs, increasing market size, and exploiting specialisation and economies of scale. This spirit of greater regional cooperation was reflected in the 1989 Asia-Pacific Economic Cooperation meeting in Canberra.

There is, however, one very important factor that we need to take into account. We must take care not to shut ourselves off from the rest of the world. If we were to do that, we would be in danger of becoming a technological backwater with the result that we would

quickly suffer reduced competitiveness.

Australia could play yet another significant role in the region. This is as educator in terms of work experience. It would be beneficial if our countries developed government-to-government schemes for work experience programs so that graduates could gain first-hand systems knowledge by working alongside experienced software engineers on major Australian projects.

POTENTIAL FOR EXPORT

Having developed software systems in Australia for almost two decades, the industry has recently begun to cast its eyes on much larger overseas markets. In almost every country that uses computers extensively, there is a need for quality products and customised development. For several reasons, Australia is well placed to become an exporter of software products and services.

While software development is people and knowledge intensive, significant capital investment is required to provide computer-aided software engineering tools. It requires people with imagination, intelligence, farsightedness, creativity, expertise and good education. These are the attributes and skills which a large number of Australians working in the industry possess. Also, costs in Australia, particularly salaries, are relatively low compared with European and U.S. suppliers. For example, based on the current exchange rate between the Australian and the U.S. dollars, Australian companies can develop software for about half the cost of firms in the United States.

Another factor in Australia's favour is that software packages are high value, easily transportable products. Unlike refrigerators, cars and other manufactured goods, it does not suffer the imposition of high transportation costs that often erodes Australia's competitiveness.

Software that can compete on the Australian market, which has been highly competitive for many years because almost every computer company in the world has attempted to gain a foothold, will be competitive overseas.

One of many changes looming on the information systems horizon is the effective implementation of open systems standards by computer manufacturers. Open systems standards mean, for example, that companies share details about the interconnection of their equipment. Thus, buyers are not locked into a particular firm's products, making it much easier for small companies to compete with multinationals. Companies other than the manufacturers will be able to gain a larger share of the original and re-equipment market. Its effects will be similar to those in the car industry where tyre, gear box and other component manufacturers have become an integral part of the automotive business.

Over the past few years, Australian companies have gained a reputation locally for producing quality systems that have proved reliable and easily maintainable in the field. Through partnerships forged with overseas-based companies, this reputation for quality has also spread to other countries.

Currently, three export markets exist for Australian software products and services. First, there is the opportunity to sell custom-built software, commissioned by a particular customer with the work being carried out in Australia and the finished product shipped overseas for installation. Second, local companies may decide to design and develop packages that they will sell locally and overseas. The difficulty here is that attempting to market these packages internationally is time consuming and expensive. Therefore, teaming up with a company that already has an international network through which the products can be distributed will undoubtedly produce the fastest and most cost-effective results. In this case the market research, marketing, selling and distribution will be largely carried out by the hardware manufacturer or systems integrator. However, the Australian company will be involved in marketing because customers frequently specify that the hardware and software be modified to meet particular needs. The third export market is for software embedded in other products. Another export opportunity is for Australian companies to train software engineers from other countries.

This exporting of knowledge and skills is already being undertaken successfully by IBM Australia. In 1988 IBM Australia generated export income worth in excess of $10 million by providing 20,000 days of training to overseas students. Customers in New Zealand, Southeast Asia, the Middle East and China benefited from IBM Australia's expertise and experience in education. Subjects included customer service, marketing, management development, banking, manufacturing and other types of technical training. In many

cases students came to Australia. In others, instructors travelled overseas.

In a similar arrangement, IBM China/Hong Kong and the Australian company, Computer Power, have agreed to set up a jointly-owned institute in Hong Kong to provide training services. Australian instructors will provide initial services until local instructors can be hired.

While for security reasons it will not be easy to provide work-experience training in defence-related software engineering to overseas students in the same way that IBM Australia is doing in the commercial area, it remains an area of potential export worth investigating.

Before an Australian company can become an exporter of software products and services, it needs to achieve two important objectives at home.

First, it needs to have technical and commercial ownership of the totality or a large section of a system. The Government has already played a significant role in helping some companies achieve this goal by placing contracts for complete systems, to be designed and built in Australia. This contrasts with the previous approach, where systems were procured from overseas prime contractors who then placed various subcontracts in Australia to undertake various unrelated segments of the total job. The Government's policy of ordering these total systems has created an environment in which Australian companies have flourished by undertaking projects that are as advanced as any in the world. This policy has had an enormous impact on local industry. Australian companies have gained an understanding of complete systems, accumulating knowledge, skills and know-how in the process.

Second, companies need to be allowed to become dominant in the Australian marketplace. They need to grow into large organisations with world class work standards and products. This dominance gives them the depth of management and financial strength needed to expand into world markets. Companies that grow into large organisations also gain credibility in the eyes of their customers in Australian and world marketplaces, with the result that they are able to readily attract overseas partners for major Australian projects. Companies achieve this dominance by designing and delivering quality systems on time, within budget and to the customer's total satisfaction.

In other words, they display excellence in everything they do. Subsidies, bounties and other artificial methods provided by some governments around the world to boost companies locally usually backfire when the company steps into a world market and is exposed to ruthless competition and demanding customers.

This thorough knowledge of complete, sophisticated systems, dominance in its local market, self reliance and sound financial backing, combined with aggressive marketing techniques, are prerequisites for international success.

THE FUTURE

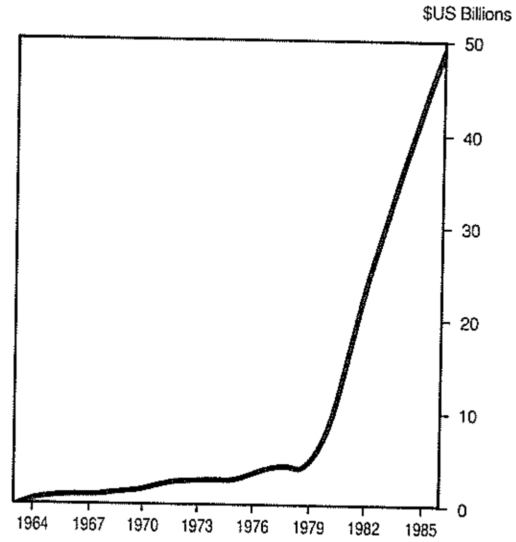
Forecasting the future in the software industry is not a simple task because the rate of change is not only fast but accelerating. However, a number of events can be predicted with a degree of certainty.

Customers will increasingly demand more complex systems and a wider range of applications. Figure 8 illustrates the dramatic actual and projected rate of growth of the world software market. This demand will place tremendous strain on the resources of the software industry which already finds life difficult attempting to keep pace with today's needs.

Technology itself will play a role in making the industry more productive. Automatic code generation will take over the work of programming, leaving software engineers free to concentrate on the key tasks of defining and designing the systems. The effect of automatic code generation will bring about a limited reduction in the cost of software.

Another growth area will be in the use of artificial intelligence. More and more military and industrial projects will be developed using expert systems, robotics or computerised vision. In an attempt

FIGURE 8
ESTIMATED WORLD MARKET FOR SOFTWARE



to reduce costs and shorten development times, companies and customers will increasingly re-use modules of existing software.

The ability of software companies to re-use modules will depend on their level of understanding the complete system, not only the segment with which they are involved. Therefore, there will be greater emphasis on selling solutions and not simply codes.

As mentioned earlier, sound software engineering principles have removed traditional black art techniques from development and turned it into an industrial process. These principles will become more widespread, making development more manageable and the results more predictable.

As customers demand a wider range of applications of ever increasing complexity, software engineering companies will have to meet these needs by specialising in selected areas. To do this they will need to gain in-depth application experience, knowledge and skills.

In a move to reduce costs and improve the performance of systems, Australian companies will cooperate with governments and companies in the Asia-Pacific region on common projects. Projects will be in the defence and commercial areas and may include air traffic control systems, communication networks and satellite switching systems.

CONCLUSIONS

I have covered a number of points and expressed some personal opinions. They are that:

- software is an inherent element in defence and industrial products today;
- a modern industrialised nation needs a firmly founded software industry;
- software engineering has joined other forms of engineering as a modern industrial process with extensive checks and disciplines;
- Australia possesses world standard software engineering skills;
- Australian systems developers participate on an equal footing with international defence suppliers;
- Australia has a comparative advantage in software development;
- Australia is well positioned to undertake the development of major defence systems locally and internationally;
- companies in Australia are making progress in pursuing export opportunities;
- Australia needs to allow the emergence of pre-eminent national players so that they can build sophisticated systems for the country's own use, thereby eliminating the need to have the work undertaken overseas. Having grown into a dominant position, these national players will progress to develop strong export markets in software, and
- there is a need for Government policies which will encourage companies in the region to collaborate on projects and products related to information technology. At the same time governments and companies need to ensure that the region does not become isolated from overseas developments and fall behind technologically.

CHAPTER 12

PROSPECTS FOR AUSTRALIAN DEFENCE INDUSTRY AND TECHNOLOGIES

Malcolm K. McIntosh

It is always difficult to follow such a distinguished group who have said everything worth saying. It is even more difficult for a Public Servant to follow a Minister.

The perspectives and policies described in this chapter have had a wide range of inputs, including the Services and Defence Public Servants here and overseas. They have also had the involvement and encouragement of the Minister who has, of course, borne the brunt of carrying them through the political process.

I am obliged by the space available to take as given the broad international and strategic framework described by the Minister (in Chapter 6) and the military strategic considerations described by Major General Baker (in Chapter 7). They are fundamental to our technological and industry policies in defence, both of which exist only for defence purposes I intend to deal first with some enduring features and then speculate on recent developments.

TECHNOLOGIES OF IMPORTANCE

We all agree that rapid technological advance in areas of military importance will continue. To pick two of the most important:

- materials and structures, affecting production methods as well as products; and
- electronics (hardware and software) in virtually everything we now buy and to meet some special needs such as C^3I.

Many advances will be driven by civil applications and taken up for military uses rather than the other way around, as has

previously been the case (for example, with computers). This will be increasingly so if and as military budgets in the main powers reduce.

Within this framework, Australia must keep up generally and seek to lead in some product areas, such as sonar and over-the-horizon radar.

However, the reality is that we will make very few of the world's technological advances. The U.S. Department of Defense spends on R&D many times the total Australian defence budget. Many major defence manufacturers (for example, Thomson CSF) employ more people than the Australian Defence Force and the Australian Department of Defence combined. Assuming people are involved in proportion to funding, and our people are, on average, as capable as anyone else's, we will have a very small fraction of the Western world's defence innovations. For the same reasons, we expect a similar outcome in civil technologies.

This requires us to direct our limited defence R&D effort to:

- products not available elsewhere. These are dictated mostly by geography (for example, hot, sparsely populated regions, approaches over long distances and shallow water), but may be complemented by the relative skill-base of population and industry.
- maintain, adapt and modernise equipment throughout its life (for example, through continuous modernisation of the F/A-18 aircraft before production is even complete), and repair through crack-patching with composite materials of the F-111s.
- more generally to be smart buyers, which requires research in a bit of all technologies and sufficient development to understand the application of technologies and to prepare industry for forthcoming projects.
- to exploit niche products from either of these areas, although the problem of funding final products with high costs and risks leads to international collaboration.

AUSTRALIAN INDUSTRY AND DEFENCE TECHNOLOGIES

It follows from the above arguments that, unless we are to have second-rate products and those at unacceptable costs, risks and schedules, most Australian defence technology will be imported. There is, however, a spectrum of local involvement, including:

- local design, development and production (for example, the *PERMUTIT* water purification for Army and the Interscan *TACAN* beacons for the RAAF and the U.S.;
- completely self-sufficient production of local or overseas designs, including the materials chain (for example, basic ammunition);
- local design embodying overseas components or sub-systems (for example, the over-the-horizon radar);
- local development of overseas designs (for example, the new submarines);
- local assembly and part local production (for example, F/A-18, *Blackhawk* and the ANZAC Ship);
- import with local maintenance (for example, F-111 aircraft);
- import and return to originator for maintenance (for example, the *Harpoon* missile);
- collaborating government-to-government design and development (for example, the *Nulka* in the U.S. and Australia);
- collaborating industry-to-industry development and production (for example, the *Raven* radios in UK and Australia); and
- design, development and production by industry with defence help purely for export (for example, muzzle velocity indicator).

An important deficiency in this list is a collaborating regional project; we are keen to explore opportunities for suitable projects with neighbours, but are yet to have instituted any significant collaborative regional projects.

The essential judgement in deciding local involvement is the cost and risks of each approach, balanced against the strategic benefits. Strategic benefits are for operator effectiveness first and foremost, followed by self-reliance in sustainability and, with lower priority, a base for expansion. Costs include invention, production and through-life support, where there are usually economies of scale in imports from larger overseas production runs.

For the design and development component, the judgements are, first, whether to select local or overseas designs or some mixture. Some of the considerations in making this decision are the risk and cost-sharing benefits, the loss of control of design and schedule of an overseas design, and the benefits of sharing export markets. The second decision is whether the local component should be developed in DSTO, industry, or some mixture. Some of the considerations are who has the expertise and special equipment, and who has symbiotic activities to be exploited now or later.

It must be noted that most countries now pursue international collaboration to share risks, costs and markets because it is beyond their means to go alone. Even the U.S. and NATO countries are in this position and Australia must expect the same. Collaboration, by increasing familiarity and interdependence, can be of strategic benefit beyond the value of the goods and services involved.

DOMESTIC FACTORS

None of the recent substantial increases in local industry involvement in Defence projects would have occurred without a range of very important wider changes, including:

- floating the exchange rate;
- tariff (subsidies in defence) reductions more equalising access to resources;
- deregulation of the financial system allowing more flexible international financing of firms and projects;
- changes in professional skills (immigration and education), yet to be resolved;

- changes in technical skills (award restructuring), far ahead of the professional sector;
- defence industry restructuring (aerospace, shipbuilding and repair, engineering, munitions and electronics), where we have selectively corporatised, privatised and encouraged mergers and other substantial changes;
- corporate restructuring (for example, ASTA, Transfield, AWA and Plessey); and
- revision of export controls and joining COCOM.

There is still much to do and some very important deficiencies, including the quantity of high quality management, although there has been something of a boom in management courses.

INTERNATIONAL FACTORS

Having got our domestic environment on the right path, the impediments are now elsewhere. Some examples are U.S. protectionism (for example, Japan, Korea and the FSX project), possible outcomes of Europe post-1992, and attitudes to and in our region, particularly as our neighbours develop economically and look to greater self-reliance in defence. Some responses to these developments can be assisted by Government through promoting collaborating opportunities. We now have collaborative Memoranda of Understanding with several countries to look for other opportunities. Having taken these initiatives, the action now rests heavily with industry to take up the opportunities that are being created.

SOME RECENT DEVELOPMENTS

It is obviously impossible for me to forecast what will happen as a consequence of the momentous changes in Europe, when experts much closer to the scene are giving differing views and the many actual decision makers have yet to decide. For the narrow interests of the defence activities relevant to Australian industry, however, the details are not very important (although they are immensely important in other respects) and some things seem fairly certain.

There will be a reduction in Western (and Eastern) defence budgets, albeit probably cautiously and more slowly than some might wish. R&D, as usual, will reduce, along with the force structures.

There will be a lot of very capable defence companies with a lot of excess capacity who can be expected to chase small markets like ours much more vigorously than in the past. This will be good for more competition and lower prices. It will be bad for competitive local content and exports. As well as new equipment, there will be a lot of cheap, used equipment.

As we did not plan to attack Europe and did not expect to be attacked from Europe, the European developments should not directly affect Australia's strategic circumstances, which are focussed on our region. It will probably, however, generate public pressure for reductions in the Australian defence vote, however illogical.

While these forecasts may be wrong, it will be safer to plan on them than to hope that they will not happen.

CONCLUSION

The future path for Australia is reasonably clear. We must invest in new technology imports and selective local developments. The domestic economic and industrial environment must be improved to facilitate local development, but more is needed. We need to work on international developments and exports far more collaboratively, with Australian sources of technology for some systems, and regional sources for others. There may be limited time before the 'windows of opportunity' close. If not, it would be a good idea to be quick anyway to get the benefits.

This approach is an essential ingredient in, and a consequence of, the international strategic developments and the force structure and military initiatives we are now taking, although exploration of those linkages must be an opportunity for another time.

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