Australian Government
Department of Defence
Defence Science and
Technology Organisation

Forward 2035

DSTO Foresight Study

Seng Boey
Peter Dortmans
Joanne Nicholson

DSTO | Science and Technology for Safeguarding Australia

First published in 2014 by the Defence Science and Technology Organisation
24 Fairbairn Ave, Fairbairn Business Park, Canberra ACT 2600
www.dsto.defence.gov.au

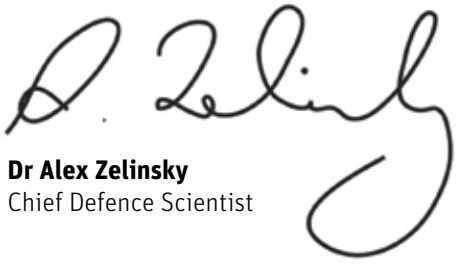
Introducing *Forward 2035*

One of DSTO's principal roles is to advise the Australian government on science and technology best suited for defence and national security. To carry out this mission, DSTO must examine the wider socio-economic and strategic global factors that shape the long-term future and its impact on emerging trends in science and technology. Currently, there are a range of studies that describe the future, the trends and megatrends that will impact and change our lives. Governments and organisations around the world routinely publish documents outlining global strategic themes and the security environment that might emerge in 20 or 30 years. We can also turn to popular literature for different perspectives.

In imagining the future, the *Forward 2035* study did something different. It carefully examined the most germane themes, contextualising them within a defence and national security setting, so that the implications for Australian Defence Science and Technology can be readily contemplated. We evaluated how these themes could play out globally and in our region; we examined new developments that may find a place in future Defence strategy and policy, such as those envisaged in the next White Paper; and we looked at how technological advances will ensure that Australian national security can maintain a competitive edge.

The outlook to 2035 is complex. Concerns of a burgeoning ageing population across developed countries are driving trends focused on health and wellbeing. Increasing urbanisation is resulting in rapidly growing megacities, particularly in our region. Equally, the sophistication of these cities is also increasing. Competition for resources will continue, straining the food, water and energy nexus further, especially when coupled with environmental changes. On the other hand, megacities are becoming smarter and greener cities offsetting some of these stresses and environmental changes. Power is shifting eastward as a result of geopolitical and economic trends, prompting the emergence of new economies, in particular the new global middle class who are redefining values and expectations, leading to new business models. Finally, it is clear that cyberspace is the medium of choice for all interactions, communications and transactions and this is, in itself, driving unprecedented change.

Forward 2035 owes its success to the exceptional calibre and creativity of staff in the DSTO Joint and Operations Analysis Division to whom I would like to extend my most sincere commendations in producing this excellent report. We trust that you will find the results of our study compelling and thought provoking. ∎



Dr Alex Zelinsky
Chief Defence Scientist

Principal Authors:

Seng Boey, Peter Dortmans and Joanne Nicholson.

Contributing Authors:

Andrew Cruickshank, Shane Dunn, Mitch Ferry, Jane Holloway, Todd Mansell, Nigel McGinty, Simon Ng, Niem Tri and Jamie Watson.

Acknowledgments

The conception, preparation and publication of this report have required a significant amount of assistance and goodwill from a large number of people.

The DSTO Foresight Workshop in July 2013 sparked many initial ideas for which we thank the participants from Defence and DSTO, and the facilitators from the CSIRO Futures team. Also, we appreciate the ideas generated from Åse Jakobsson's series of creative elicitation workshops on Defence megatrends.

The DSTO-RAND Workshop in December 2013 inspired the framing of the ideas. In particular, we are grateful to Richard Silberglitt (RAND Corporation) and Timothy Brown (Royal Australian Navy) for their advice in shaping the general form of the report.

We are grateful to the expert reviewers: Mehrdad Baghai (Alchemy Growth Partners), Alan Dupont (Professor of International Security, UNSW), Brian Hanlon (Research Leader, DSTO), Stefan Hajkowicz (Leader CSIRO Futures) and Mark Hinchcliffe (Royal Australian Air Force). These reviews suggested additional material and provided important nuance.

We want to thank Peter Baxter (Deputy Secretary of Strategy, Defence), John Blackburn (former Deputy Chief of Air Force), Doug Kean (Office of National Assessments) and Brendan Sargeant (Chief Operating Officer, Defence) for generously spending time in discussing the main thrusts of the report and identifying key defence context.

We appreciate the effort of Scott Wheeler for analysing the vast amount of data; David Pulford for the rigorous pursuit of key references; and Jimmy Hafesjee, David Kilmartin, Neelam Naikar and Luciano Rossato in editing and designing the publication.

Abbreviations

ADF	Australian Defence Force
DSTO	Defence Science and Technology Organisation
R&D	Research and Development
S&T	Science and Technology
STEM	Science, Technology, Engineering and Mathematics
CSIRO	(Commonwealth Scientific and Industrial Research Organisation)

Contents

Preface i

Executive summary 2

Introduction 4

Complexity 6

Change 12

Opportunity 16

Emerging Science and Technology (pullout) 18

Demands 24

Summary 30

Executive Summary

Australian Government documents released over the past twelve months indicate that Australia's strategic environment is undergoing fundamental change, and at a rapid rate.[1, 2] Key to this change is the rapid economic growth of the Asia-Pacific region. In particular, as the Australia in the Asian Century White Paper notes, *"The global centre of gravity is shifting [sic] to our region, the tyranny of distance is being replaced by the prospects of proximity. Australia is located in the right place at the right time".*[3] These developments will bring profound changes to the lives of people in our region. Along with the economic shift, the Asia Pacific is also experiencing increasing military modernisation.

As CSIRO have also pointed out, Australia is well placed to benefit from this shift.[4] Investment in research and development (R&D) is strongly coupled to this eastward shift. Therefore, rather than resting on our laurels, we need to adapt to the transformation of wealth away from nations with natural resources to those that place a premium on the emerging technologies. While the *tyranny of distance* no longer poses a challenge, our size does, both in terms of geography and population. So we need to be selective about where and how much to invest: should we be a world leader, a fast-follower, or an interested bystander? Aligning our niches with our needs will give us a capability edge.

This study examined a range of global trends and identified four major implications for Australian Defence and its science and technology. The following ***implications*** should become apparent to the reader through four stories presented in the main report that are set in the 2035 timeframe and are focussed around ***complexity, change, opportunity*** and ***demands:***

- **Mastering Complexity:** population growth and geography are leading to an increasing complexity in urban centres, where competition for resources will increase along with growing congestion of supply chains. Civilian and military infrastructure is becoming even more highly interconnected and interdependent, whilst current military systems are already so complex they are pushing boundaries of manageability. Nations that can master this complexity will attain a distinct technology advantage over peers and competitors.

- **Trust in Technology:** demographics forecasts coupled with developments in technology are driving change in the nature of work. Nations will increasingly need to balance the "employment" of humans and "intelligent" machines (such as autonomous systems). Establishing trust in machines to undertake an ever increasing range of tasks will require a deep and fundamental

understanding of intelligent autonomous systems technologies. However, adopting such technologies can only occur after addressing the significant cultural, legal and ethical challenges.

- **Smart Power:** economic development in the Asian region is presenting many business and commercial opportunities for Australia beyond the resource sectors. The growing investment in R&D across Asia presents an opportunity to enhance diplomatic and cultural ties through the shared language of science, with Australia already having a strong R&D based on linkages to US and Europe.

- **Innovation Enterprise:** emerging social structures (the global middle) and expectations within the region are driving corporations to change their business models to meet new demands. National boundaries are becoming less important in the commercial world and most nations will increasingly lose access to industrial surge capacity during times of national need. Agile manufacturing will fundamentally change the way Defence views capability innovation. Defence will need to adapt to this new world, and learn to exploit the opportunities that arise as we transition from a “just in time” to “built on demand” paradigm. ■

*"**We're at the beginning** of the most rapid transformation ever seen by technology."* [5] *Jason Pontin (2013)*

*"**The [21st] century** will witness an even more far-reaching scientific revolution, as we make the transition from unravelling the secrets of Nature to becoming masters of Nature."* [6] *Michio Kaku (1998)*

Introduction

We are currently going through a significant shift in science and technology development. New technologies are emerging and rapidly evolving as they build on each other. Analysts from the Revolution of Military Affairs (RMA) Program at the US Naval Air Warfare Center have noted that the convergence of a number of overlapping technology trends, occurring over the next 10 to 15 years, will lead us through the information age to the robotic-biotech age.[7] In traversing the information age, knowledge is being created, disseminated and applied at an astounding rate – scale, precision, reach and speed being the defining attributes.

Overall, this technological revolution will transform everyday life, commerce and the means of production. In short, we are seeing a fundamental and far-reaching shift in the nature of the human condition. At its core is the convergence and integration of technologies. There are five important emerging technology areas that DSTO has identified, and is currently examining, to help Defence maintain a competitive advantage. (See pullout at page 22). We envisage that these will influence a wide range of activities, processes and perceptions in Defence, possibly for decades ahead.

The transition from discovery (of science and technology) to mastery (over them) is a socio-technical phenomenon, where innovation and creativity are the keys to success. According to MIT Professor Lester Thurow, "In the 21st century, brainpower and imagination, invention and the organisation of new technologies are the strategic ingredients".[8] Taking this view of the primacy of human creativity, we framed our study of future possibilities from a people-centric perspective. Our study examines the likely and potential impact of the rapidly changing global trends on human societies from the perspective of Australia's defence and national security needs. To paint a vivid picture of the emerging situation, the trends are presented in the form of four principal stories focused on **complexity, change, opportunity,** and **demands.** Side stories are presented throughout to illuminate key elements of the broader themes. This rendering of the future possibilities seeks to position DSTO at an advantage in understanding the ***implications*** of the emerging trends for its own investment program, and for that of Australian Defence as a whole over the next twenty years. ◘

Complexity

Global population growth

In July 2013, the world population reached 7.2 billion - 648 million more than in 2005 or an average gain of 81 million persons annually. We can be reasonably certain about some elements of population change. Certainly, the broad pattern of global population growth up to 2035 is largely predictable. However, there is still debate about the exact numbers based on a range of assumptions about attitudes, food availability, conflicts, and the health of populations. According to the medium-variant projection, the world population is expected to reach 8.6 billion in 2035 and 10.9 billion in 2100, even assuming that fertility levels continue to decline.[9]

Australia's population rank is unlikely to shift significantly by 2035, even if it experiences a dramatic increase in migration. By 2035, Australia's population is projected to be about 30 million (see Table 1).[10]

By 2035, almost 80% of the world's population is projected to be in Asia and Africa, as depicted in Figure 1. Almost all future population growth will be in the world's less developed countries.[12]

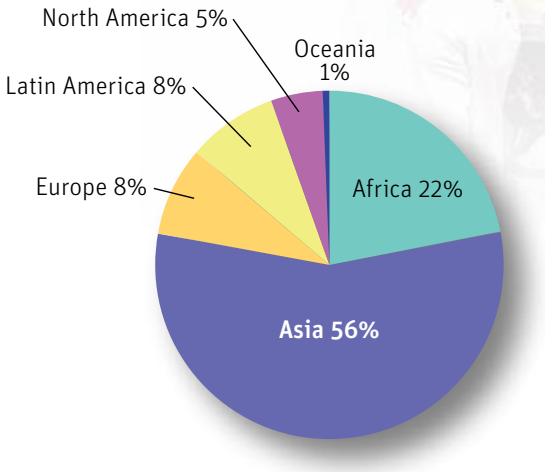


Figure 1: World population by Region in 2035 (compiled using data from[13])

Age range	1970	2010	2020	2030	2040	2050
Population as at 30 June (millions of people)						
0-14	3.6	4.2	4.9	5.4	5.7	6.2
15-64	7.9	15.0	16.6	18.2	20.0	21.6
65-84	1.0	2.6	3.7	4.8	5.6	6.3
85 and over	0.1	0.4	0.5	0.8	1.3	1.8
Total	**12.5**	**22.2**	**25.7**	**29.2**	**32.6**	**35.9**
Percentage of total population						
0-14	28.8	19.1	19.0	18.3	17.4	17.2
15-64	62.8	67.4	64.7	62.4	61.3	60.2
65-84	7.8	11.7	14.3	16.6	17.2	17.6
85 and over	0.5	1.8	2.1	2.7	4.0	5.1

Source: ABS cat. no. 3105.0.65.001 (2008) and Treasury projections.

Table 1: Australian population history and projections[11]

While there is general consensus between the many models of population growth, there is great debate about what this means for planet Earth and the people that share the basic resources of food, water and energy. Many models estimate that there is enough food to avoid mass starvation, but this food is not distributed evenly, potentially creating a situation that, as in historical times, can be a pretext for conflict.

Furthermore, according to United Nations' projections, the population is ageing.[14] By 2035, the four largest countries in Asia will have witnessed significant increases in people over 64 years old, both in absolute numbers and as a proportion of the total population. Increasing urbanisation will mean that an even larger proportion of this ageing population will be living in 'megacities'.

The rise of the megacity

In 2035, 60% of the world's population will be in cities, with 80% of all urban growth occurring in Africa and Asia. Pushed by population growth, industrialisation and a range of technological developments, we will see the emergence of megacities as the dominant physical and social landscape of the 21st century. The United Nations projects that urban environments will account for more than 75% of the earth's population by 2050; half of these urbanites will reside in Asia. The number of megacities will nearly double over the next two decades, rising to more than 40. Over half of these will be located in Asia.[15]

Space limitations mean megacities will be characterised as vertical cities; increased demands for resources will promote green cities; and advances in digital technologies will foster smart cities. In the developed world, where growth occurs more slowly, megacities will aspire to be integrated, networked, and branded; delivering zero emissions, zero waste, zero accidents and zero security breaches. Infrastructure will focus on rapid and efficient transit networks. Electric and automated vehicles will become the norm.

In the developing world, significant internal migration from rural areas will see rapid expansion of urban areas, overwhelming the megacities' capacity to cope. Pollution, appropriate housing, affordable health care, quality education, reliable energy provision, food security and, in some cases, an ageing population, will challenge infrastructure. Income disparity will exacerbate social tensions. Dislocation from communities will challenge societal norms.[16]

The Indian Ocean is now surpassing the Atlantic and Pacific oceans as the world's busiest trade corridor. Rapid economic growth in South, Northeast and Southeast Asia

Environmental change

Environmental change has the potential to impact a wide range of requirements including water resource availability, food production and distribution, energy supply and demand, particularly fossil fuel consumption.

Increasing demand for water resources for food production, mining and urban areas, and greater variation in availability and water quality, could lead to greater use of water recycling and desalination.

Increasing threats to food security associated with availability, accessibility and affordability will arise. Decreasing availability of agriculturally productive land and water, coupled with increasingly severe weather events and variability in rainfall events and distribution, plus national food holding policies (e.g. export restrictions) would lead to reductions in globally traded food supplies with consequent increases in food prices and decreases in accessibility in high population growth areas.[17] In particular, ocean acidification, glacial melt, increasing sea temperatures and changing ocean and wind currents will affect fish stocks in specific regions, though over-fishing remains the primary challenge for fisheries globally.

The emergence, or re-emergence, of infectious diseases for humans, animals and plants globally could occur. Changes in the distribution of diseases and pests, or expansions of disease and pathogen vectors could be realised through modern transport. Prompt outbreak reporting and assessment, e.g. using social media, and development of on-demand vaccines, through nano-engineering for example, will at least partly mitigate these threats.

Greater global demand for energy will continue, placing pressure on fossil energy sources unless new sources, e.g. shale gas and tight oil, are exploited. However, these may be restricted by demands for reduced carbon emissions stimulating demand for nuclear and renewable energy generation, particularly electricity for industry, commercial, residential and transport applications.[18] There will be an increased need to use non-energy resources sustainably; this includes recovery, re-use, remake. Technologies and processes to support sustainable use are being developed, trialled and/or commercialised.[19] Increased emphasis will be placed on 'cleaner' forms of transport. Current focus is on improvement to mass transit systems and electrification of transit and freight systems.

Increased urbanisation and city growth across the world will place more pressure on existing infrastructure and transport and waste disposal systems but provide greater opportunities to efficiently provide food, water, shelter and employment for growing populations. In addition, the concentration of human populations in megacities, could enable the retention of productive land for food production. ◘

is driving stronger economic links with the resource-rich Middle East and Africa. One-third of the world's bulk cargo and around two-thirds of global oil shipments now pass through the Indian Ocean. These increasing trade flows are highlighted in Figure 2 which depicts the density of trade flowing through Indo-Pacific waterways.

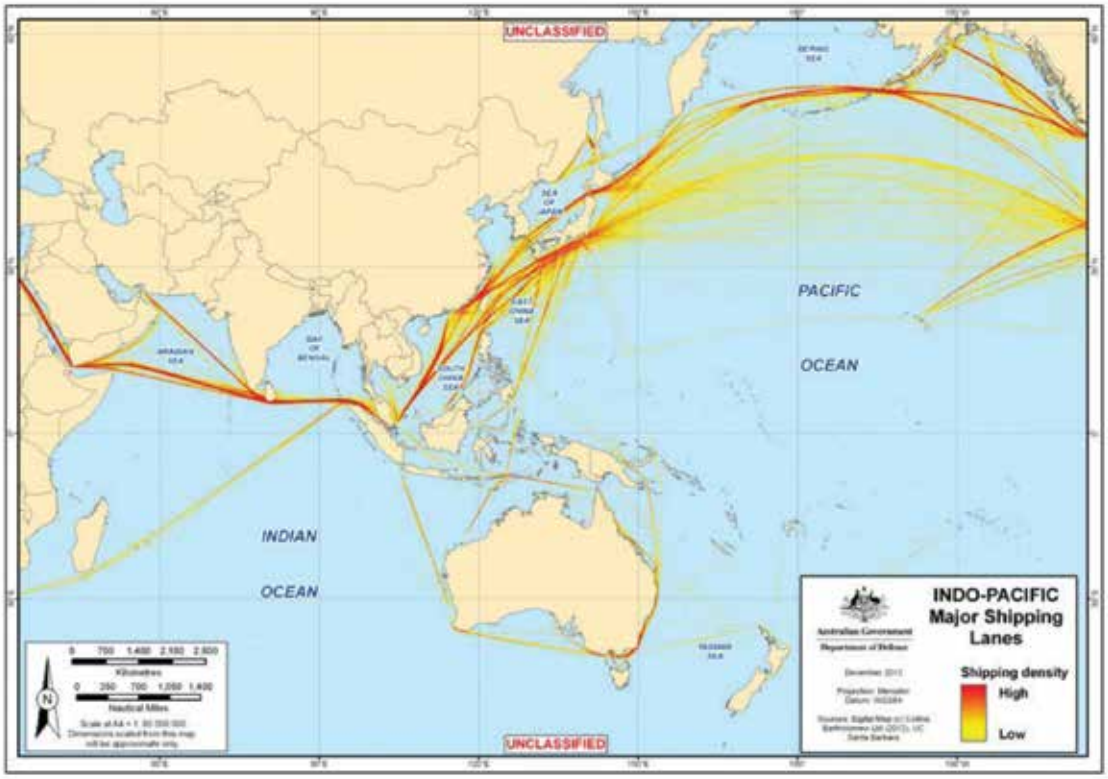


Figure 2: Intensity of major-shipping lanes through the Indian and Pacific Oceans transiting Asian waterways.

Australia and its major trading partners - China, Japan, Singapore, India and the Republic of Korea - have direct interests in stable trade routes through the Indian Ocean. As an example, over 80% of China's oil imports transit the area. With the economic advantage in the large-scale transportation of goods there also comes a vulnerability to sea-borne threats. Operations in and through littoral environments are inextricably linked to these economic and security drivers, and will likely have significant implications for our future maritime strategy.

Infrastructure and interdependency

Megacities, due to their sheer scale, as well as the unique trajectories of their emergent formation, pose special challenges for security, governance, planning and monitoring. Control over these environments will challenge the legitimacy of governments in cases where activist groups, or criminal

organisations, are seen to operate freely. Attempts to consolidate, or even adequately network, surveillance, tracking and tracing systems embedded in the environment will become increasingly challenging.

Australia will not see the emergence of a megacity by 2035. The Australian Bureau of Statistics (ABS) projects that Melbourne and Sydney will both have of the order of 6.5 million inhabitants by 2051.[20] However, we will be affected by the rise of megacities in our region. Australia may find itself needing to support operations in such large urban environments particularly given that most of the Asian megacities will be in areas prone to natural disasters. Supplying these megacities with mineral, agricultural and other resources will present opportunities for Australia, and should shape how Australia invests in infrastructure, science and technology and service provision. Australian cities might also benefit from the technologies that are developed for and by the megacities to sustain them, in areas such as communications, energy and power, transportation, and efficient design.

An important consideration is the development of critical infrastructure; both our own and in areas where we conduct operations. Infrastructure grows and evolves globally through unplanned aggregation of isolated parts; adaptation to unanticipated demands; and transformation of services according to social needs. As such, critical infrastructures are complex systems; it is generally impossible to abstract global behaviour from the analysis of single components, especially under conditions such as failures or disasters.[21] Therefore, we need to understand the general principles leading to the complex global architecture of these systems which are often heterogeneous and display different types of interdependency.

Physical interdependency exists when energy, material or people flow from one infrastructure to another. Cyber interdependency exists when information is transmitted or exchanged. Geographical interdependency arises from close spatial proximity of infrastructure elements. And, logical interdependency is associated with finance and political coordination.[22] When building, maintaining and upgrading our critical infrastructure, all these interdependencies need to be considered. For example, complex computer control systems networked through ubiquitous

communications systems are becoming commonplace and rapidly evolve through hardware, firmware and software updates. Such systems will have physical, cyber and geographical interdependencies. These systems also utilise components procured via convoluted supply chain arrangements which in themselves are networks with physical, cyber and geographical dependencies. In short, civilian and military infrastructure are becoming hyper-complex (i.e. highly interconnected and interdependent).

Furthermore, these systems will be sufficiently networked such that catastrophic network failures may occur in unpredictable ways when aberrant behaviour from one or more systems occurs. Simplistic models indicate something akin to a phase transition occurs where failure of a few nodes in one network abruptly leads to disruption of connections in a second coupled network. Shortly thereafter the entire system becomes fragmented. Isolated networks tend to degrade continuously.[23] Two mutually interdependent networks can become more fragile than each network in isolation.

With ever increasing threats from malicious cyber activities by nations and non-state actors, the challenges of assuring our complex networked systems has never been greater. In addition, the provenance of components upon which systems are built must be assured. ■

Considerations for Defence

Mastering complexity

The scale, size and complexity of megacities need to be understood – this cannot be underrated and we might even refer to warfare in this environment as ***"complex warfighting on steroids".*** *In particular, the crossover between military and civilian technologies and infrastructure that's challenging today's military force is likely to be amplified and accelerated in megacities. Successful megacities will drive technology development; unsuccessful ones will be sources of instability. The lines between military and security operations can be expected to be further blurred. Operating concepts exploiting emerging technologies focussed on predictive analytics and non-lethal effects will help to achieve operational requirements in these congested, complex environments. Predictive analytics could also be utilised to identify vulnerabilities of our shared civilian and military infrastructure/equipment. By exploiting complex systems theory, strategies can be developed to address failures with minimum disruption to services. The use of lethal means will present extreme risks of fratricide and unacceptable levels of collateral damage. Where lethal means are still required, high levels of precision will need to be achieved – the speed of decision cycles afforded by autonomous aids can have a role in achieving this precision. Success in future security operations in megacities is likely to be effected through influence and shaping activities.*

Are we prepared for the complexity of the megacities and the challenges presented by the highly interconnected and interdependent critical infrastructure?

Change

Rethinking trust

The increasing prevalence of, and dependence on, automation should not be underestimated. Automation is already deeply embedded in our day-to-day existence. Automated traffic systems increase physical safety, data management systems reduce cognitive load, and automated logistics systems remove the need to undertake menial or repetitive tasks. Society, as a whole, trusts these systems. Failure is rare or a minor inconvenience.

Expert systems employing artificial intelligence (AI) will form a pervasive and largely invisible component of everyday life. These systems will reduce demands for decision and action within the workplace. Many decisions, and associated actions, will be automated or delegated to autonomous entities. People will be freed from menial tasks and protected from ill-informed actions.

As AI systems improve, the transition from semi-autonomous to fully autonomous systems will occur. These will lower the risks to workers and could assist in lowering the cognitive load of humans by having action delegated to automated systems where appropriate. Furthermore, implanted diagnostic tools will provide real-time health monitoring, with the capacity to automatically release medication. Medical interventions could be automated through wireless transmission of the diagnosis to a medical provider.

As technologies such as AI, data management and robotics mature and combine, opportunities to defer action and decision to automated systems will arise. However, so will the likelihood and consequence of failure. Trust will emerge as a major issue - one to which Defence, given its role, will be particularly sensitive.

Personal avatars are on the horizon. The emergence of Web 4.0 provides an immersive environment where all aspects of the physical and virtual persona seamlessly converge. Virtual agents will initiate actions and make suggestions, tailored to the individual's personal needs. Trust will form an intrinsic part of this relationship as confidence is built. But risks will increase as this confidence leads to increasing deference to these virtual entities.

The rate of technology-refresh requires ongoing attention when attempting to keep pace with cutting edge information and communications technology (ICT). The need for assurance and trust that systems are functioning properly is challenged by the dynamic nature of virtual environments and the rapidity with which society is willing to adapt to change. Strategies that mitigate these risks need to be developed.

Confidentiality, integrity and availability of information have become critical enablers. The speed of action in cyberspace can render the typical human-centric decision cycle irrelevant and will drive us towards increasing trust in autonomous systems and in the integrity of the shared use hardware and networks they rely upon. However, adversary action that can undermine such trust could render capabilities useless. Not being able to exploit these new technologies through a lack of agility risks operational stagnation.

Autonomous systems will reduce the need for warfighters to be in the firing line and provide greater mobility and a broader range of employment. However, engagement within the virtual environment will challenge Defence's traditional modes for Command and Control. The relative speed with which warfighters transition through their decision cycles (whether situated in the battlefield or remotely from it) can determine who retains the initiative as the slower side finds itself trapped in a cycle of reaction. In an attempt

to gain an advantage in the operational tempo, greater delegation to automated systems may be enacted - however, this may only be achievable through the acceptance of lower trust thresholds and increased risks to human life. How much loss would we be willing to tolerate especially if it arises from non-human mistakes?

Ageing Australia

In Australia, towards 2035, the number of people aged 64 and over will grow faster than the number younger than 64 (see Figure 3). Percentages over the next 30 years will decrease for the working age population, as shown in Table 2.[24]

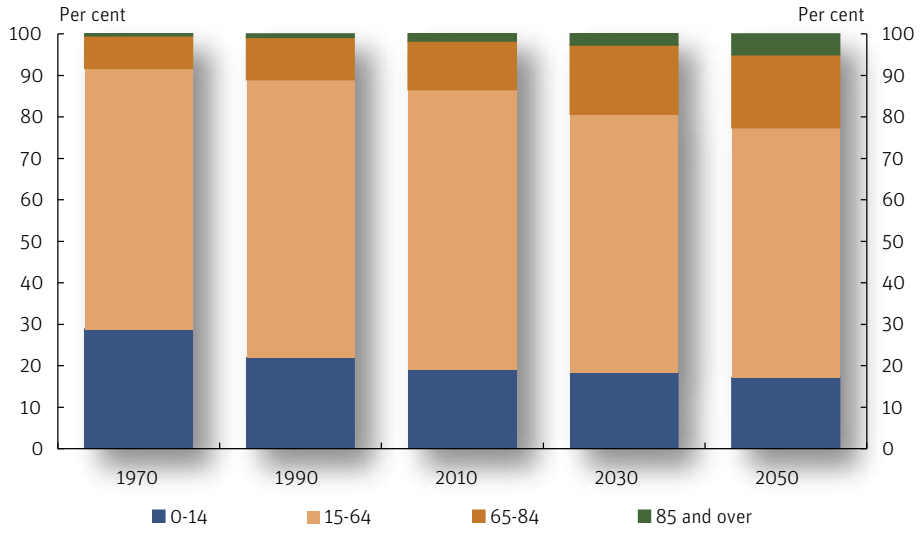


Figure 3: Proportion of the Australian population by age groups.[25]

	10 yrs to 2010		10 yrs to 2020		10 yrs to 2030		10 yrs to 2040	
	CHANGE	LEVEL	CHANGE	LEVEL	CHANGE	LEVEL	CHANGE	LEVEL
POPULATION	1.55%	22,299,775	1.41%	25,642,412	1.22%	28,947,313	1.00%	31,985,490
WORKING AGE POPULATION	1.78%	18,081,351	1.52%	21,017,317	1.30%	23,916,047	1.09%	26,664,950
EMPLOYMENT	2.25%	11,056,539	1.65%	13,018,012	1.19%	14,652,881	0.91%	16,040,868

Note: % changes are average annual changes. Levels are figures as at the end of the period.

Table 2: Economic forecasts for Australia.

The productive capacity of Australia and populations with similar ageing profiles will be challenged as human resources will be required across different sectors of the economy. Conversely, technologies that improve life-long health and wellbeing will lower the incidence of chronic conditions, reducing the resource demands required to support the elderly in an ageing population.

Developments associated with health and wellbeing (underpinned by developments in biotechnology and cognitive neuroscience) will lead to people living longer, being much healthier and having enduring cognitive abilities. Workforce participation, particularly among ageing countries, will be enhanced as levels of chronic illnesses are reduced and cognitive fitness is increased. Therefore, a worker's age may become less significant or, at least, the ceilings associated with age and performance may need to be reassessed and possibly extended. Furthermore, the experience that comes with age could be exploited, especially if the complexity within work environments continues to increase.

While an ageing Australia will affect the current ADF recruitment base, the future workforce demands could be readily met. This is especially true if consideration is made of the impacts that automation and virtual environments will have on the very nature of the work conducted. ◘

Trust in technology

Defence will have to adapt to changes in the nation's human capital. The reduction in the proportion of the working age population, the greater workforce demand across the economy, and the increasing competition to attract the workforce that remains will mean that Defence will have to be more flexible in the composition of its workforce. ***"Enhanced people"*** *will become an enduring feature of the workforce as increases in effective working lives due to advances in biotechnology leading to enduring cognitive and physical capacities are realised which may potentially mitigate workforce pressures. Developments in autonomous systems will radically change many currently labour-intensive, menial or high-risk activities. Machines taking on these roles will ensure that Defence personnel are free to do the things that people do best.*

Currently, while there is much focus on the cultural, ethical and legal issues associated with the use of autonomous systems, questions still remain regarding how much trust we can place in information, automation or autonomous systems and the level of error we are willing to tolerate in machines, in particular. ***"Cyber trust"*** *will emerge as a new phenomenon, and Defence, given its role, will be particularly sensitive to this.*

Defence needs to examine what its requirements are likely to be in 20 years and identify roles that can be performed partially or completely by autonomous machines. This examination will lead to questions relating to the difference in trust we place in humans over machines. Strategic personnel planning, or force structure models, that demonstrate explicitly how new technologies will change what is required and who (or what) might undertake such roles need to be developed. These models should comprise a Defence workforce where age, physical and cognitive profiles align with the demands of a more technologically complex environment. The adoption of biological monitors and predictive diagnostics tools to proactively manage health can be expected to help enable greater use of an ageing workforce.

We tolerate mistakes made by humans, but can we afford to do the same with machines: where does the threshold lie?

Where do we best employ our valuable human capital in Defence?

Opportunity

The economic shift to Asia

There has been a profound shift in economic power over the past decades. A major global trend is Asia's re-emergence as a critical economic region. According to the Australia in the Asian Century White Paper, this is a defining feature of the 21st century.[26] The growth, economic strength and scale of Asian manufacturing have significant implications worldwide. Australia's future prosperity is tied to the security and strong economic growth of Asia.

Asia has long been seen as an attractive region for developed economies to locate manufacturing bases and in 2007-08, for the first time in over two centuries, the majority of the world's economic growth took place in the developing economies, significantly driven by China, India and other Asian economies. Unsurprisingly, a key component enabling this growth has been lower labour costs and a plentiful labour market.[27]

To highlight the extent of this shift, China's economy grew over 30% and India's grew 22% in real terms between 2009 and 2012. In contrast, Germany's economy grew only 7.9% and the United States' only 7.1% over the same period.[28] The McKinsey Global Institute (MGI) has analysed the global economic "centre of gravity" being the geographic mid-point of global activity.[29] Figure 4 shows how this has moved from a European focus, at the start of the Industrial Revolution, to a central

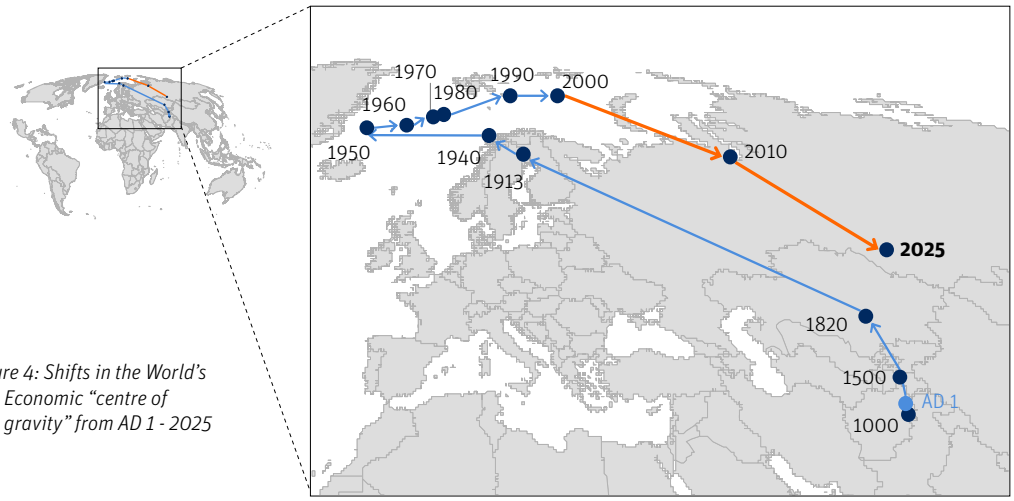


Figure 4: Shifts in the World's Economic "centre of gravity" from AD 1 - 2025

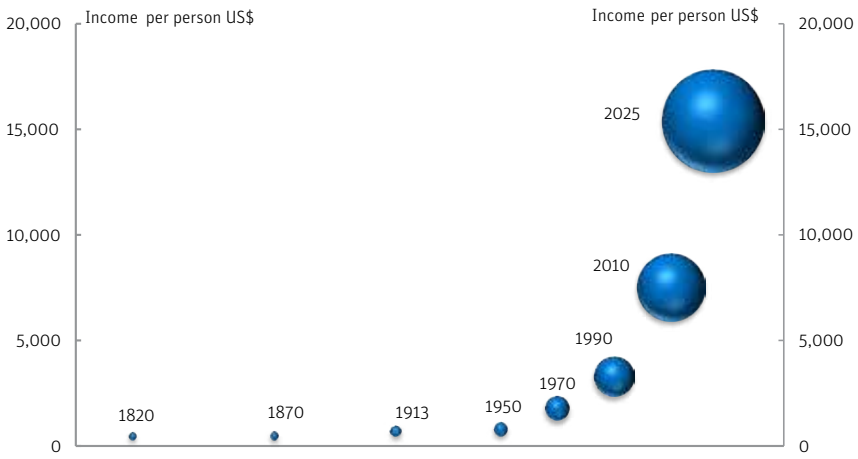


Figure 5: Asia's economic resurgence is set to continue. The blue circles reflect the size of GDP for Asia's economies, adjusted for purchasing power parity in 2011 prices. (from p.50 in Australia in the Asian Century White Paper)

Asian mid-point. MGI projects the movement to continue towards Asia, at a slightly slower pace, for the next 15 years or so. This economic growth in turn drives personal wealth. Figure 5 illustrates the exponential growth in the historic and projected income on a per person basis. In the past 20 years, China and India have almost tripled their share of the global economy. By 2025, it is projected that Asia, as a whole, will account for almost half the world's output.[30]

CSIRO defines the opportunities offered primarily by Asia in the *Silk Highway* trend.[31] It states that the economic shift will build new export markets, trade relations, business models and cultural ties for Australia.

Going global, a positive development

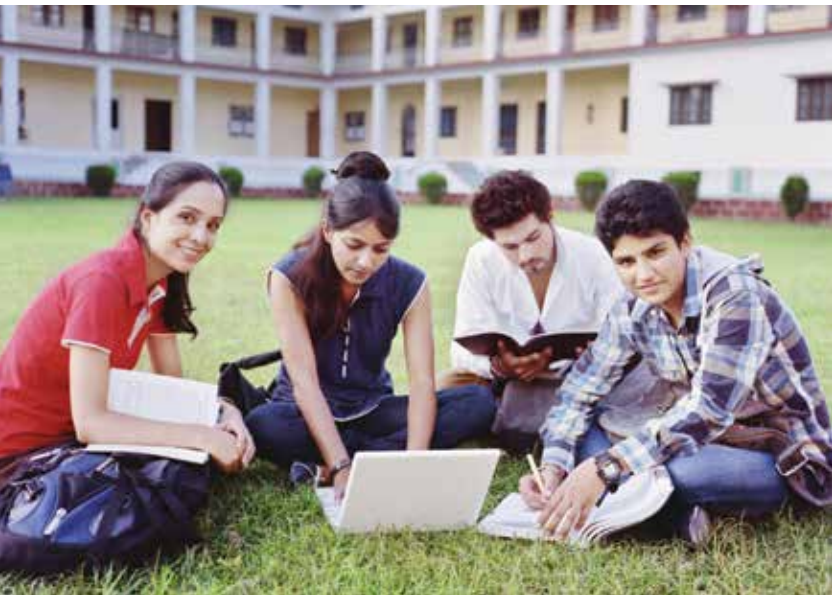
Globalisation and new technologies are increasing the flows of people, information, services and goods. These are overwhelmingly positive developments. An increasingly wealthy and mobile middle class is emerging throughout the region, creating urbanisation, consumption and new opportunities. Asian nations will continue to transform investment in knowledge development and indigenous manufacturing capability. The transformation of Asian nations is highlighted by the changing nature of international research collaborations and patents. Australia's strong academic collaborations with North America and Europe will continue, but the greatest growth in collaboration is occurring in emerging areas of scientific and technological strength in Asia.[32, 33]

Globalization of R&D has accelerated in the past decade through a combination of R&D funding growth in emerging economies, off-shoring and outsourcing of a portion of western R&D, improved communications and the need for larger-scale, interdisciplinary collaboration on major scientific challenges. In the commercial sector, innovation capabilities tend to follow the wealth created by manufacturing, catalyzed by accelerating product development cycles and sometimes by regulation. …China is designing and building state-of-the-art next-generation nuclear power plants, a space station, highspeed rail systems, military and commercial aircraft and other major projects—many of which draw on global science and technology assets.[34] Batelle (2013)

Shifts in R&D expenditure

US economists Edward Prescott and Finn Kydland won the 2004 Nobel Prize for Economics by demonstrating that there is a symbiotic relationship between R&D and economic advantage.[35] They showed that new technologies were directly responsible for, and generally a defining factor of, economic booms. It follows that if countries wish to attain or maintain a competitive advantage they should invest in R&D. It is not surprising, then, that R&D expenditure mirrors overall

economic growth.[36] All major economies nearly doubled their R&D expenditure from 1991 to 2011, rising from roughly $740 billion to $1.5 trillion in constant 2011 dollar terms.



Developing countries in Asia are investing heavily in growing their economies through innovation and technical expertise, promoting significant growth in innovation capacity and outcomes. Figure 6 depicts the gross domestic expenditures on R&D (GERD) as a percentage of Gross Domestic Product over time for a number of countries. The figure shows significant increases in expenditure for China, Taiwan, The Republic of Korea and, at a slower rate, Japan. The traditionally strong innovators, including the US and France, are exhibiting a more steady investment in R&D. In 2011, China was second only to the US in both R&D performance and scientific publications. The quality of these publications is still behind most OECD countries, but China's increased collaboration with the US (more than 10 fold from 1998 to 2011) could soon remedy this issue. While the US continues to dominate global R&D with over USD 400 billion of domestic R&D expenditures, twice that performed in China, according to Battelle, *"at current rates of R&D investment and economic growth, China could surpass the U.S. in total R&D spending by about 2022".*[37]

R&D expenditure is strongly correlated to the quality of military capability 10 to 25 years later.[38] Given the growth in R&D investment, this correlation suggests that Asian nations will continue to narrow the gap in quality of military equipment compared to Western countries. Additionally, as many Asian countries have been investing considerably for the last 10 to 15 years, we may be nearing a tipping point where high quality capabilities become available for commercial and military applications. *(Continued page 19).*

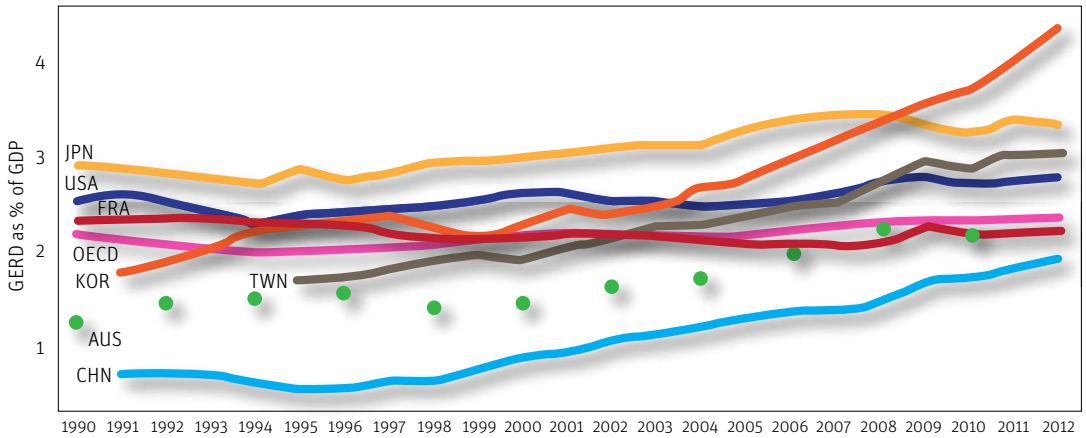


Figure 6: R&D intensity. The diagram plots the gross domestic expenditures on R&D (GERD) as a percentage of Gross Domestic Product for a number of countries.

Emerging science and technology areas

Today we are on the cusp *of an epoch-making transition, from being passive observers of Nature to being active choreographers of Nature.*[1] *Michio Kaku (1998)*

The emerging technology areas DSTO has identified, and is currently examining, to maintain a competitive advantage for defence and national security, represent some of the underlying forces that will drive change in concepts of operation, processes and perceptions both in and of Defence. They could thus be described as megatrends in their own right. There are strong overlaps between these technology areas and, importantly, it is through these overlaps or technology convergence that the most interesting applications may arise. According to Irvine and Schwarzbach, "...our world is actually being driven by nine overlapping, emerging technology areas, each advancing at its own rate and each at a different point along its individual development curve."[2] (Figure 1). Whilst each technology area has particular pertinence for Defence, the technology areas also reflect the trends and interests of the broader community.

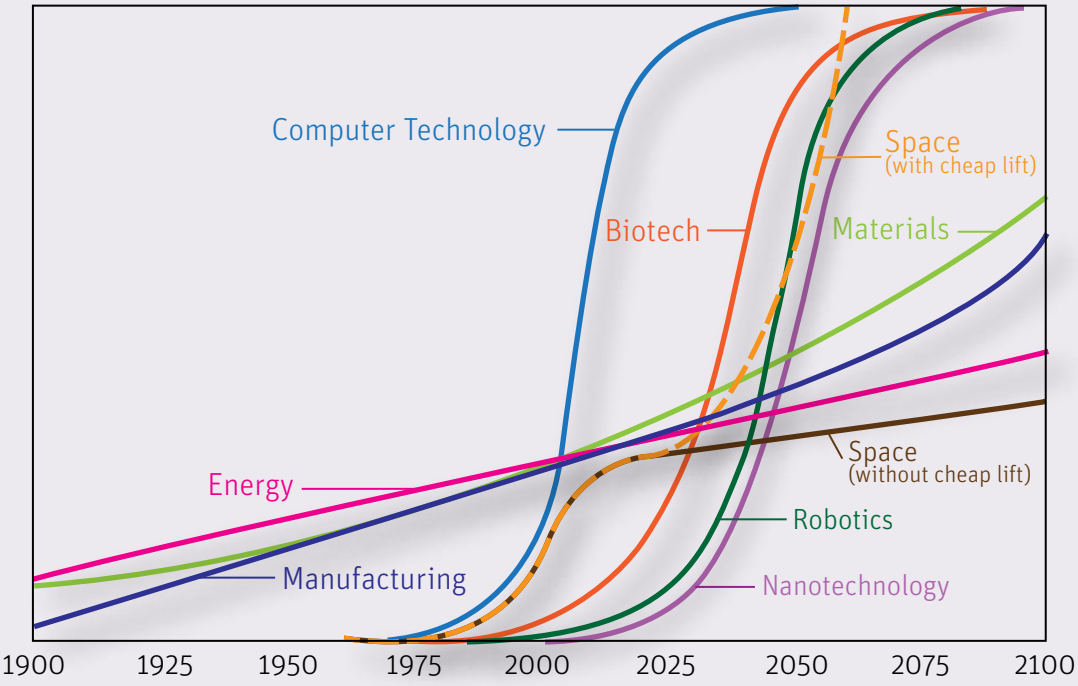
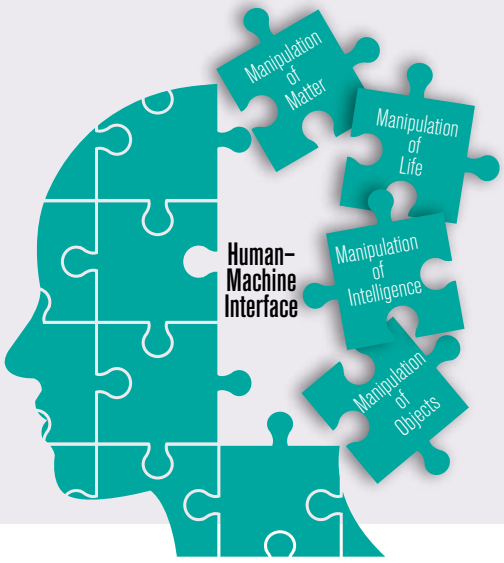


Figure 1: Overlapping of Emerging Technology Areas

Human systems are concerned with the technological systems that support a human in decision making and the issues regarding the amount of data that a human has to process. Cognitive abilities are being challenged in the age of big data. The problems extend beyond information availability and overload (which remains an ongoing challenge for Defence) to include the design of technologies that can improve the gathering, accessing and fusion of data, so that the right information is supplied to enable informed and timely decision making. This falls into the traditional domains of intelligence, surveillance and reconnaissance (ISR) and command and control (C2) in Defence.



1 Kaku, M. (1998) "Visions: How Science will Revolutionalize the 21st Century and Beyond", Oxford University Press, Oxford

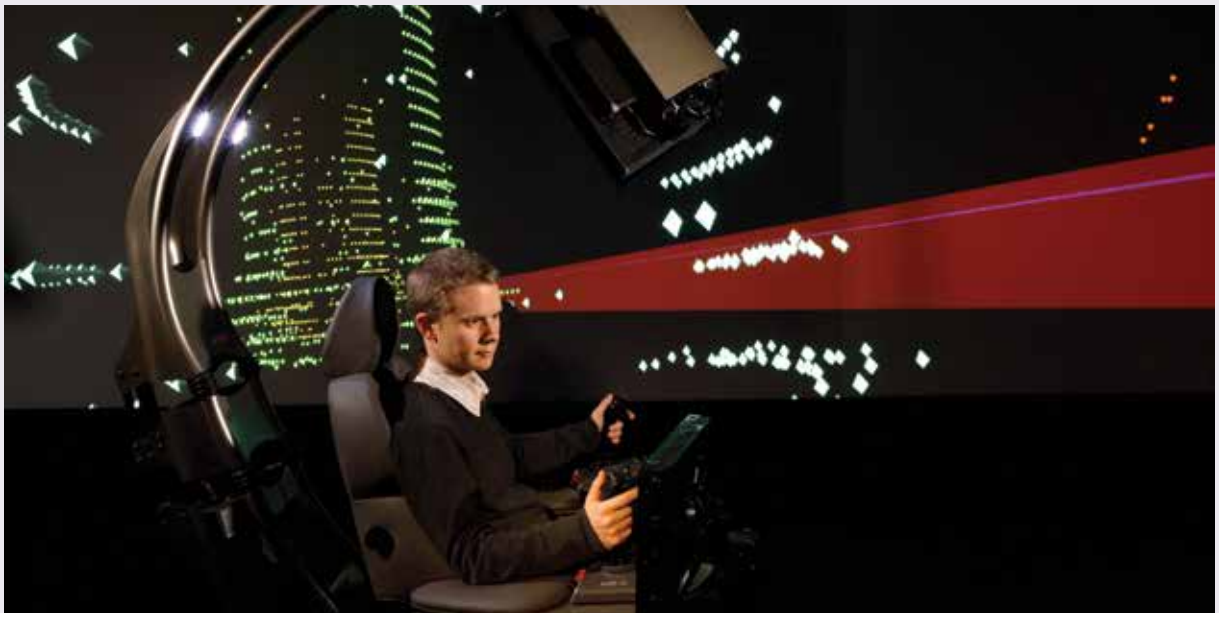
2 Irvine, J.H. & Schwarzbach, S. (2011) "New Technologies and the World Ahead: The Top 20 Plus 5", The Futurist, May-June, Vol. 45, No. 3

The wide diffusion of sensors and computing capabilities into everyday environments will effect a major paradigm change for thinking and for designing technological and social systems. Continued growth in computational resources will enable a new level of pattern recognition, including patterns of complex emergent behaviour. And, understanding in enormous amounts of data and mathematics will be used to decode processes in everything from biological to social systems.

All this will ultimately challenge our perceptions of traditional ISR and C2 and we will need to reshape our thinking about how we manage, monitor and interpret these new trends, without further compounding the already anticipated sensory overloads. For example, when individual mobile devices, incapable of determining the exact location by themselves, begin to collaborate with other devices, location awareness suddenly emerges. This technological development may be exploited when we are trying to locate or detect an entity, but it could be a vulnerability if we wish to remain undetected.

Advances being made in cognitive neuroscience and augmentation may provide mechanisms to reshape the way we think. The ability to tailor technologies to individual nuances, preferences and cognitive abilities should maximise and optimise decision making powers.

Manipulation of Intelligence: Cyber. Whilst we have discussed the profusion of data, and how it impacts our decision making, cyber represents the need for confidence in the information that is collected, in how it is disseminated and, ultimately, in its security. This is of paramount importance to national security. Technologies such as IP hopping, network polymorphism, massive virtualisation and rapid network recomposition are being developed to make cyber systems inherently resilient to intrusions.



Society is increasingly operating in cyberspace to connect with, deliver and access services, to obtain information and to perform transactions. This is enabled by traditional computer networks, with a growing reliance on wireless transmissions. Similarly, digital media is allowing people to form new connections and selectively access information through multiple channels with subsequent erosion of trust in traditional sources. But, can we trust these new sources and are new vulnerabilities emerging through our engagement in cyber space?

Manipulation of Matter: Advanced Materials. Moving from cyberspace to the material world, the manipulation of materials at the micro and nano scale level is enabling the production of more sophisticated materials on a range of scales enabling the miniaturisation of devices and the development of lightweight, low cost materials as well as the invention of new materials. Metamaterials are being used to develop hand-held terahertz devices, which will be capable of medical scanning and imaging, stand-off bio-hazard detection, stand-off explosives detection and through-wall imaging challenging us to rethink how we currently operate.

Computer hacking.

3D printing.

The confluence of new materials and distributed intelligence will lead to a new kind of infrastructure that is dramatically reshaping the economics of moving people, goods, energy, and information. A particular application of this is agile manufacturing which may well revolutionise supply chains in Defence logistics, where, by utilising intelligent, secure networks, the CAD file for a required part can be delivered to a local 3D printer manufacturing point in theatre for *in-situ* production on an as-needs basis. Conversely, bespoke capability, unique for purpose, may be manufactured quickly. The availability of 3D printing and the simplicity with which designs can be uploaded and modified, however, means anyone can design what they want and build it.

Manipulation of Life: Biotechnology. While advancements in metamaterials is causing us to rethink the way we conduct operations, biotechnology is concerned with protecting and enhancing biological systems, including humans. Developments in biotechnology can be categorised into five different areas: synthetic biology, detection and treatment technologies, bioinformatics and individualised medicine technologies. Synthetic biology is of particular interest in that it offers the potential to make designer organisms that break down waste, as well as produce food, fuel, biomass, polymers and drugs. However, these developments also require a new kind of vigilance to ensure such powerful new technology is not used nefariously.

Wearable sensors.

Whilst countering the nefarious application of some of this technology is of great importance to Defence, the constructive application of potential developments in this area to the warfighter in the battlefield necessitates additional consideration in Defence. Equipping warfighters with comfortable wearable sensors and computers that will enhance self-awareness of health condition, environment, chemical pollutants, potential hazards and the like will provide overall improved battlespace awareness. Utilising this information to then allow predictive diagnostics to be undertaken and individualised medicine to be administered would enhance the ongoing health and safety of warfighters and the conduct of operations in a range of different environments.

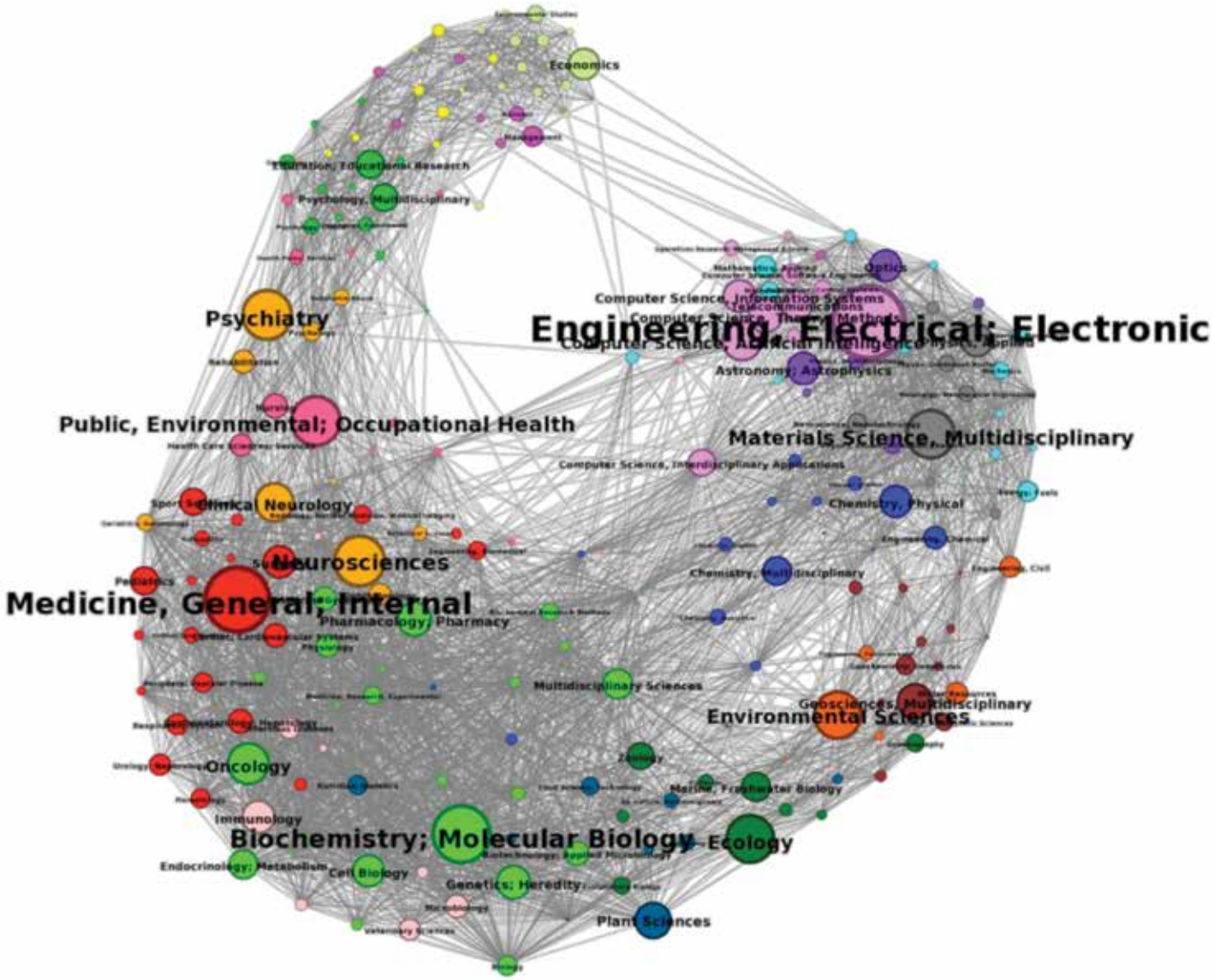
Manipulation of Objects: Automation is concerned with the automatic operation of equipment, a process, or a system, and it has several drivers including ageing population, increasing labour costs, industrial automation and leveraging by able-bodied people. For Defence, it is this last driver that is most pertinent as we strive to put fewer warfighters at risk, or at less risk. Conversely, we may replace warfighters or people altogether and utilise autonomous systems that represent the next great step in the fusion of machines, computing, sensing, and software to create intelligent systems capable of interacting with the complexities of the real world.

Uninhabited aerial and underwater vehicles are already in use. Autonomous sentinels that perform perimeter surveillance and defence and autonomous sweepers for improvised explosive device (IED) detection, land-mine detection or continuous autonomous route patrol will all be useful in safeguarding Australia. For Defence, a challenge will be to decide what levels of machine autonomy are acceptable in what circumstances. ◘

Innovation involves creative, skilled and motivated people[39] and collaboration is a source of creativity.[40] A bibliometric study conducted in 2013 examined Australian research production and collaboration over the preceding 10 years (2002-2012).[41] Overwhelmingly, the US and UK are our top collaborators with China ranking third in collaboration statistics, and Japan, Singapore, India and the Republic of Korea in the top 20. The citation impact for all our collaboration indicates that the quality of our papers is greater because of collaboration rather than without. This finding accords with the OECD Review[42] that international research collaborations are considered to be of higher quality and impact as demonstrated by the number of citations of the subsequent scientific publications. Examination of the affinity of Asian countries, in particular China, India, Japan and the Republic of Korea, for collaboration with Australia indicates that there is opportunity for Australia to increase its level of collaboration, leveraging off its current successful collaborations (but not to the detriment of it).

The comparative science maps[43] from the bibliometric study in Figure 7 show the similar research interests between Australia, the US and the UK; conversely there are some points of difference between the concentration of research in Japan and China. A question that arises is: Do we look to leverage off points of difference in

Australia

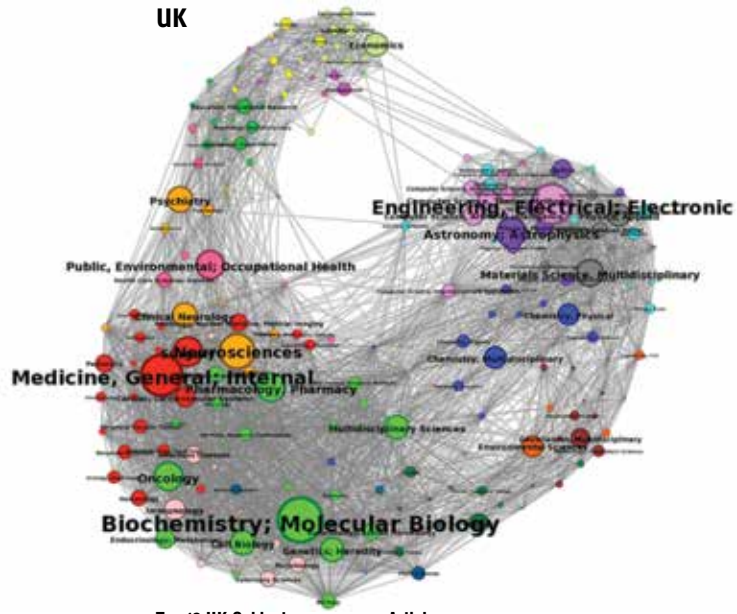


Top 20 Australian Subjects	Articles
Medicine	30154
Ecology	25081
Electrical and electronic engineering	21655
Immunology	18558
Oncology	17358
Surgery	17155
Cell biology	16982
Public health environmental and occupational health	15627
Biochemistry	15146
Ecology evolution behavior and systematics	14952
Physiology	14890
Condensed matter physics	14192
Genetics	12904
engineering	12528
psychiatry and mental health	12223
microbiology	12214
psychology	12205
physics and astronomy	12130
plant science	11471
nursing	11375

Figure 7: Comparative WoS Science Maps (2002-2012).

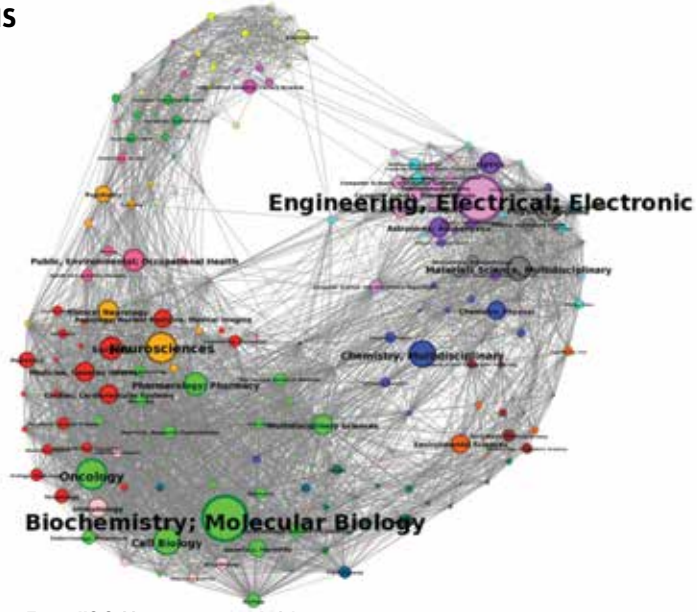
[Note: the size of bubbles are to scale within each map, but are not to scale across maps]

UK



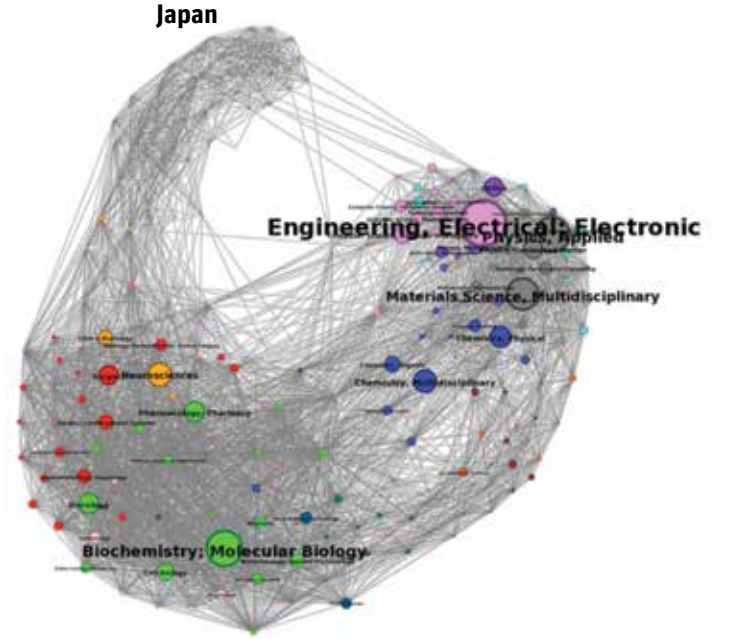
Top 10 UK Subjects	Articles
Biochemistry Molecular Biology	50052
Medicine General Internal	43757
Engineering Electrical Electronic	42427
Neurosciences	37311
Surgery	32549
Pharmacology Pharmacy	31093
Astronomy Astrophysics	30509
Oncology	29062
Public Environmental Occupational Health	28963
Psychiatry	26827

US



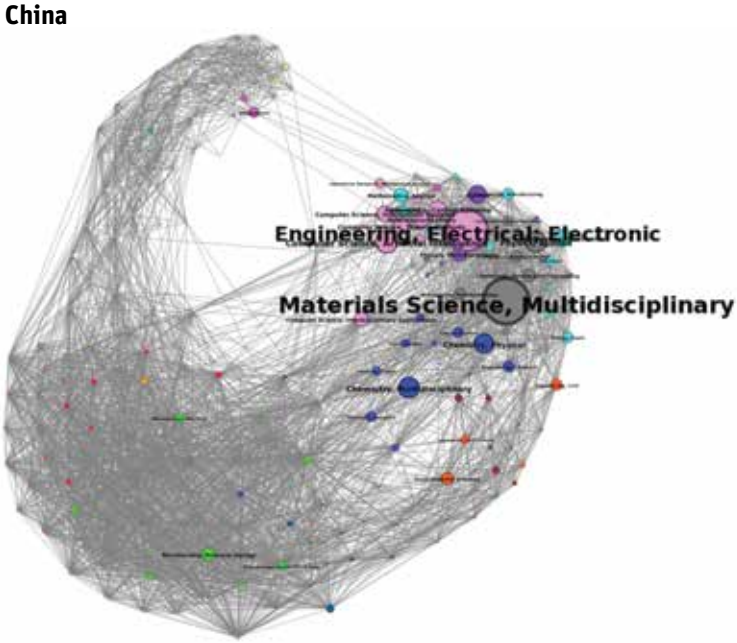
Top 10 US Subjects	Articles
Biochemistry Molecular Biology	250928
Engineering Electrical Electronic	235864
Neurosciences	153337
Cell Biology	143918
Oncology	142126
Chemistry Multidisciplinary	133519
Pharmacology Pharmacy	110431
Materials Science Multidisciplinary	109047
Surgery	108768
Physics Applied	107872

Japan



Top 10 Japan Subjects	Articles
Engineering Electrical Electronic	77933
Biochemistry Molecular Biology	62564
Physics Applied	57670
Materials Science Multidisciplinary	51458
Neurosciences	38897
Chemistry Multidisciplinary	35653
Pharmacology Pharmacy	34006
Chemistry Physical	32493
Oncology	31717
Surgery	31410

China



Top 10 China Subjects	Articles
Materials Science Multidisciplinary	185538
Engineering Electrical Electronic	184512
Computer Science Artificial Intelligence	101552
Chemistry Multidisciplinary	79761
Physics Applied	78418
Chemistry Physical	76225
Computer Science Information Systems	67379
Optics	67047
Computer Science Theory Methods	66992
Automation Control Systems	65225

Figure 7: Comparative WoS Science Maps (2002-2012).

[Note: the size of bubbles are to scale within each map, but are not to scale across maps]

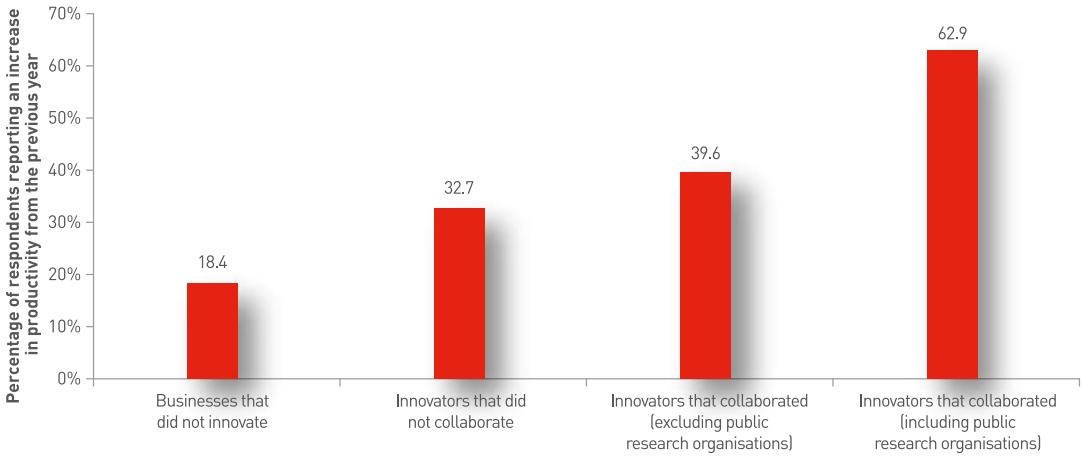


Figure 8: The effect of innovation and collaboration on firm productivity, 2010-11

research interests between ourselves and potential collaboration partners or do we capitalise on extant strong research interests of the collaboration partner? Addressing this issue will help to identify the specific STEM capabilities that should be the focus for developing new collaborative opportunities, while at the same time maintaining our existing strong R&D collaborations.

The Australia in the Asian Century White Paper also asserts that to compete in the Asian market, Australia should build upon its advantages in its advanced education and training systems.[44] The OECD reports that students who seek education away from their home are an important source of knowledge flows between countries. High-quality tertiary education attracts skilled individuals in search of training and career opportunities, some of whom later return to their home countries.[45] The US (710,000) attracts the highest number of international students, followed by the UK (420,000), France (268,000), Australia (263,000) and Germany (177,000).

A recent article, highlighting what international higher education students in Australia study and where they come from, revealed that their enrolments are concentrated within a small number of fields. Management and commerce are the most popular higher education field, followed by engineering and related technologies, IT, and 'society and culture'. In particular, the article states that almost one in four foreign university students take one or more STEM subjects and more than half of the international students enrolled in postgraduate research are in STEM-related courses, with Chinese students dominating the numbers.[46] Therefore, Australia's international tertiary student enrolment

should provide an excellent platform for building ongoing international collaboration as well as mutual understanding and social, cultural and business links. In addition, internationally mobile scientists have been shown to produce research with greater impact.[47] Australia should seek mutual benefits by exploiting our innovation skills and proximity to Asia to partner with Asian nations on science and technology programs.[48]

Similar initiatives already exist and are best illustrated by the Australian Innovation System Report 2013. It espouses that the *"…core message of* [their] *report is that the rise of Asia presents many opportunities for Australia beyond the resources sectors. …the comparative advantage of Australia's proximity to Asia needs to be complemented with its competitive advantages in innovation and better knowledge of the Asian markets".*[49]

The benefits of collaboration are demonstrated in the Australian Innovation System Report 2013 where it is shown that collaborative innovation with research organisations more than triples the likelihood of business productivity growth (see Figure 8).[49]

Commercial investment in R&D drives technology transfer: how we may influence the investment needs to be determined. Through such initiatives, Australia could retain indigenous technological capabilities that deliver a competitive, strategic edge. ◘

Considerations for Defence

Smart power

Many Asian countries have been investing in R&D heavily for the past 10 to 15 years, and may have reached a tipping point in realising this investment as commercial and military capability solutions. This transition from discovery (of science and technology) to mastery requires innovation, creativity and collaboration.

There are opportunities for Australia's innovation system to partner with Asian nations capitalising on our close proximity. Australian R&D capability and our education and training system should be utilised as national strategic assets, enabling the application of ***"smart power"*** *through regional collaboration. Science diplomacy provides opportunities to build regional engagement and, ultimately, national prosperity and security. Prepositioning us to contribute in co-creation through our R&D capacity can give us access to innovative capability, countering concerns of losing technological superiority. Against this broad landscape, we can make strategic investments in key areas where we can achieve competitive advantages for Australia. We will need to determine the specific STEM capabilities that present the best platforms for innovation and which complement our engagement with the growing Asian and existing R&D communities. Furthermore, we will need to consider the areas where Australia must retain indigenous technological capabilities to maintain a strategic edge.*

Can Defence exercise "smart power" to influence the national R&D agenda?

Demands

Rise of the global middle

The global middle is loosely defined as people with incomes that surpass some absolute level of consumption – that is, they have some disposable income to spend on durable and luxury items as well as experiences. This group is predicted to grow to 4.9 billion in 2030 (out of a projected global population of 8.3 billion).[50] The bulk of this growth will occur in Asia, particularly China and India[51, 52] (see Figure 9).

This middle class own durable assets (houses and cars) which they want, and expect, the government to protect. Middle-class people want security for their families, and choices and opportunities for themselves. The middle classes have a direct interest in shaping government policy (to ensure the preconditions for continued economic benefit) and making government accountable. Generally, though, the middle class is better educated and tends to value democracy, individual freedom and tolerance for alternative lifestyles.

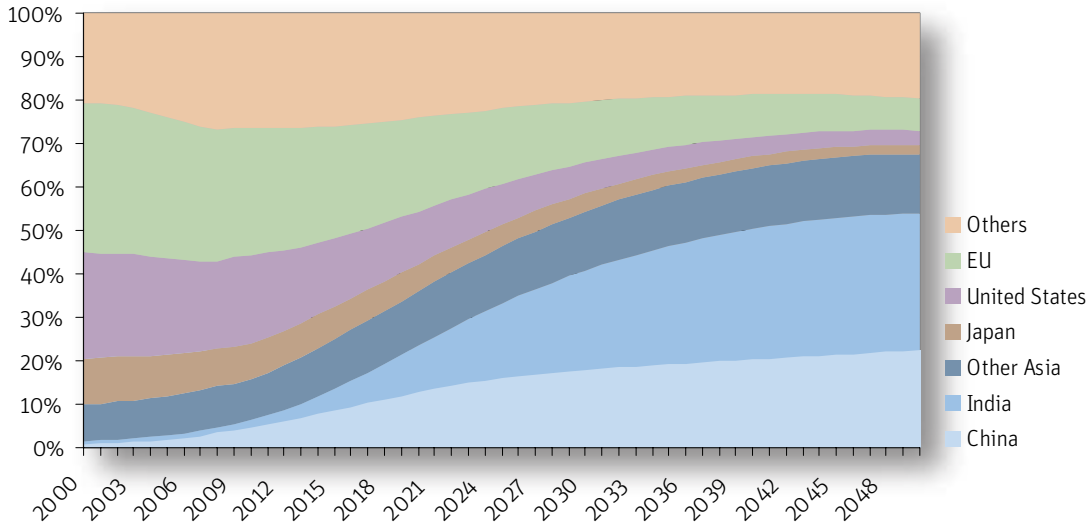


Figure 9: Shares of Global Middle Class Consumption, 2000-2050[53]

Today, the global economy relies heavily on Western consumption, with products and services tailored to their needs. In 2035, Asian countries, especially China and India, will drive consumption. The rise of the new global middle class, in particular an Asian middle class, will result in big shifts in tastes, products, fashions, and designs.[54] Acting mostly out of self-interest, their growing voice (due to higher purchasing power) will push governments and corporations to introduce reforms and improved service delivery in areas that are beneficial to them.

Changing demands

The talent, ingenuity and resources in the population are being used to solve problems in commerce and R&D.[55] The global middle understand that people are more effectively motivated intrinsically (through social contact, intellectual stimulation, social recognition) rather than extrinsically (by money). Individuals willingly give their time and money (for example, through the phenomenon of 'crowd funding') to support a cause they believe in. Social media is the essential component to crowd sourcing as it allows organisations to reach a wider audience faster, cheaper and more efficiently. Social media is being supported by technologies such as faster internet, cloud computing, distributed computing and online storage and processing. Niche groups will develop and network in novel ways to tackle problems.

Hyper-inequality - informal authority and influence

"*... inequality remains high, with the top 10% of the world population owning 86% of global wealth, compared to barely 1% for the bottom half of all adults*" [56] Credit Suisse (2013)

Super Rich: In 2008, there were no Chinese billionaires compared with 470 in the US; by 2013 the number of Chinese billionaires had grown to 122 compared to 442 in the US.[57] Over the same period, the combined wealth of these billionaires had grown from 4.4 trillion to 5.4 trillion USD. This trend shows both a shift in the wealth, and therefore influence, from the US to China. More important, though, is that the super rich were also well-connected, with 30% of the top 50 billionaires serving in government advisory roles (though mostly in China). This trend is expected to continue and we can expect this group of self-made super rich to continue their influence in the world forum through informal influences.

Defence must understand how informal networks function and their influence.

Poor: There is a strong correlation between nations with large internal income inequalities, and high levels of health and social problems. Governments that do not address significant inequalities in access to service, healthcare and education will face significant internal threats. Megacities that fail to manage this, or lack the capacity to sustain this, may become hot-spots for discontent and, hence, breeding grounds for urban terrorism. ◘

At the same time, declining material consumption is occurring with people becoming more focussed on activities and experiences as their basic physical requirements are met (refer to CSIRO's *Great Expectations Megatrend* [58]).

Tools like blogs, forums, Facebook™ and Twitter™ are shifting the power balance from company to consumer. It allows users to compare prices, review products and voice their opinions. Consumers have always had a voice, but now it's louder and it spreads quickly because of social media. There are numerous anecdotes of consumers driving companies to backtrack decisions.[59] This generation of consumers is versed in harnessing the power and energy of the individual to make meaningful changes.[60] They are able to orient the crowd's moral compass to pressure governments and firms to their goals: from stopping live exports of animals to the phasing out of palm oil products. Technologies in communications and new forms of networking will enable citizens to coalesce and challenge governments and multi-billion dollar corporations.

Agile manufacturing

New business models, offering customisation and personalisation, are emerging to meet these differing demands. In line with the idea of customisation and of advertising to consumer groups, agile manufacturing technologies will enable tailoring of products for the consumer. In fact, it is possible that the consumer will become integral to the design of the final product.

Agile and new manufacturing technologies are likely to minimise waste and inventory holdings. Rapid developments and production also mean companies are quicker to adapt to changing market trends and preferences. Shorter development cycles will also produce superior products as faults are rectified and improvements made as required. Social network sites will enable consumers to create their own products and services. According to Booz Allen Hamilton, the big cost to

Diggerworks is an example of customised procurement.

customisation is complexity[61] and companies must find the right balance between the value that customisation brings to their customers and the costs it can impose.

Logistics will be revolutionised. "Just in time" will be replaced by "Built on demand". The requirement for Defence to maintain and protect long lines of supply and communication will be reduced. Most replacement parts will be made on site and on an "as-needs" basis. Replenishment will be simplified with the raw ingredients being flat packed and capable of rough handling. Only very specialised components (e.g. computer chips) or consumables (e.g. fuel) will need to be sourced elsewhere.

During military operations, the need for recovery operations will be reduced, as vehicles gain the capacity to build some of the simpler and less resilient or harder wearing components. Quality control will be less of a problem as the replacement part will only need to last long enough to leave the theatre and return to base.

Energy and power represent a limiting factor, particularly in difficult or contested terrain. The need to operate these systems will add an extra burden. As such, improved energy management systems as well as *in situ* energy production are essential to realise the full potential.

Agile manufacturing will supplant many conventional manufacturing approaches as it provides great flexibility to personalise products in an economically viable way. This may present Australia with better bargaining power in procuring customised capabilities that meet niche needs. We must also acknowledge that threats to Defence equally exist from adversary uptake of agile manufacturing technologies and processes.

With these changes in the nature of the commercial world have come real changes in technologies – and the way technologies are developed. The 'sharing economy' - allowing co-development, co-payment, and socially-sourced projects - has enabled a direct interface for technology developers to multiple market segments, before a technology is released. This significantly reduces development risk and has been responsible for a marked increase in technology startup activity across the world.

The sharing economy makes use of multiple technical platforms (ranging from crowd funding and collaborative design software through to micro-equity venture capital options and direct retail investment in private companies (inspired by the Jumpstart Our Business Startups Act, better known as the JOBS Act of 2012, and the international copies it inspired afterwards).[62]

National boundaries are becoming less important in the commercial world and most nations will increasingly lose access to industrial surge capacity during times of national need. Few developed nations will be able to sustain mass-production manufacturing.

Commercial sector accounts for 75% of space economy.

This relaxation of boundaries and increasing propensity to off-shore manufacturing may in turn lead to concerns of provenance in supply chains. In addition, control of triple use (commercial, civilian and military) capabilities, such as logistics, surveillance and communications, will be increasingly ceded to multi-national compacts and commercial interests. For example, according to the Space Foundation, *"The global space economy grew by nearly 7% in 2012, reaching a new record of $304.31 billion. As in previous years, the vast majority of this growth was in the commercial sector, which now constitutes nearly three-quarters of the space economy, with government spending making up the rest."*[63]

Commercial opportunities in space mean that total investment in commercial ventures will outstrip investment in undertakings for national security purposes. Commercial and public interests will often colour and, sometimes trump, national military interests. ◘

Considerations for Defence

Innovation enterprise

Defence will have to adapt to a new world where it does not have full control of its critical capabilities. It must determine how to harness the new 'sharing economy' business models. Defence can be adaptable to future events by leveraging new business models. Value-add will be derived in innovation and design phases. Exploiting S&T investment in emerging technologies, can afford Defence greater ***"bargaining power"*** *in its influence of the new commercial world. For example, agile manufacturing will revolutionise logistic systems from 'just in time' to 'built on demand' with improved efficiencies in-situ and supply chains and provision of better quality or fit-to-function solutions for warfighters. The requirement for Defence to maintain and protect long lines of supply and communication will be reduced but protection of sovereign capability and/or information will remain paramount. The prize to Defence for leveraging the new business model is a lean development and innovation process, which will ensure that Defence can be adaptable to future events and has equal say in the triple bottom line.*

How does Defence ensure access to "national infrastructure" when needed?

Innovation and adaptivity

Innovation and adaptivity have always been hallmarks for long-term success in business. Now, time to respond has compressed bringing agility to the forefront of business models. The combination of the rate of technology change, the convergence of those technologies, changing social expectation and global connectivity mean that businesses that fail to adjust are doomed.

Commerce may no longer be value-free as consumers become more activist and more connected. Companies that have adapted to the triple bottom line business model (profit, social and environmental) will have a competitive advantage – a loyal customer support based on trust. Companies that effectively exploit big data will be able to manipulate and shape consumer behaviour and trends. Companies that focus on niche and quality will become attractive to the rising global middle where people are seeking status through differentiation.

Those growing up in the virtual world are well versed in harnessing the power and energy of the individual to make changes. They connect with others seeking to pressure governments and businesses to align with their values. Social and environmental issues will form part of how that generation balances cost with benefit.

The act of commerce is moving to the virtual domain. Physical presence is no longer critical. Increasing consumer demands for the on-line when purchasing goods and services, along with marketing through social media are shaping business strategies. Collection of personal data through these means in conjunction with geo-location of services will enable businesses to employ personalised push marketing. The future consumer is always active and available.

Niche will become the new 'black'. Smaller developed nations can no longer depend on mass-production as a sustainable means of commerce, as off-shoring and automation pushes manufacturing to low-cost countries. Even larger nations are not immune, as seen by the death of the car industry in Detroit. Motor City now finds itself financially bankrupt and unable to meet many of the social demands expected in an advanced economy.[64] In the future, tools are cheap, while information is essentially free. Innovation, entrepreneurialism and knowing your niche will be the basis for the competitive edge. ◘

Summary

Mastering complexity

Pushed by population growth, industrialisation and a range of technological developments, the 'megacity' (with a population in excess of 10 million) will become the dominant physical and social landscape of the 21st century. The majority of these megacities will be situated in Asia, be primarily coastal (in areas prone to natural disasters) and be supplied through extraordinarily complex critical infrastructure (water distribution, waste management, electricity generation and distribution, transportation and communications systems).

Driven by rapid technological development, critical infrastructure will become increasingly complex to build, maintain and upgrade. Complex computer control systems, networked through ubiquitous communications systems, are becoming commonplace, and rapidly evolve through hardware, firmware and software updates. These systems utilise components procured via convoluted supply chain arrangements. In short, civilian and military equipment/ infrastructure are becoming highly interconnected and interdependent, thus compounding complexity. Nations that can master this complexity will attain a distinct technology advantage over peers and competitors.

Implications for Defence

The most challenging national security or defence operations will be those conducted within a megacity. Holding a square kilometre of ground in a megacity will require more effort than at any other point in history. In particular, the crossover between military and civilian technologies and infrastructure – already challenging today's military force - is likely to be amplified and accelerated in megacities. Successful megacities will drive technology development; unsuccessful ones will be sources of instability.

The utility of traditional lethal means will be greatly reduced in the face of extreme risks of fratricide and unacceptable levels of collateral damage.

Infrastructure and military systems are becoming so complex that they cannot be tested against all operating conditions. Furthermore, these systems will be so highly networked that catastrophic network failures may occur in unpredictable ways when aberrant behaviour from one or more systems occurs; conversely, failure may be avoided when other networked systems take over functions from defunct or corrupted systems. With ever increasing threats from malicious cyber activities by nations and non-state actors, the challenges of assuring our complex networked systems have never been greater. In addition, the provenance of components upon which systems are built must be assured.

What next?

Operating concepts must incorporate the scale and complexity of megacities and the complexity of highly interconnected and interdependent civil and military infrastructure. Emerging technologies focused on predictive analytics and non-lethal means may fulfil operational requirements in these congested, complex environments. Predictive analytics could also be utilised to identify vulnerabilities in our shared civilian and military infrastructure.

By exploiting complex systems theory, strategies to address failures with minimum disruption to service could be developed. In operations requiring the application of force, where lethal means are still required, high levels of precision will need to be achieved – the speed of decision cycles afforded by autonomous aids may have a role here. Success in future security operations in the complex urban terrain of megacities is likely to be effected through influence and shaping activities.

Trust in technology

The demands for confidentiality, integrity and availability of information will present challenges for Defence as commercial technologies and information become more integral to its business. The increasing prevalence of, and dependence upon, automation should also not be underestimated. Automation and virtual environments will change the very nature of the work conducted and, at the very least, cause a rethink of workforce profiles. Currently, while there is much focus on the cultural, ethical and legal issues associated with the use of autonomous systems, questions still remain regarding how much trust we can place in information, automation or autonomous systems and the level of error we are willing to tolerate from machines.

Implications for Defence

Deferring to virtual entities to make decisions and initiate actions will increase. As confidence in these virtual entities grows, they will be trusted with controlling complex critical infrastructure and systems. In the battlespace, automated decision making could render the human-centric decision cycle irrelevant in some cases.

Competition within a shrinking workforce, exacerbated by an ageing Australian population, will affect the ADF recruitment base driving decisions towards greater use of appropriate technologies. Automation and autonomous systems offer a potential reduction in the demand for labour-intensive, menial or high-risk work activities. Machines taking on these roles will ensure that the employment of Defence personnel from the available workforce is optimised.

In short, to maintain a capability edge, Defence needs to determine what processes it can automate, what autonomous systems it should invest in and how it can develop trust in these new cyber force elements.

What next?

The appropriate and planned introduction of autonomous systems into defence and national security operations will require an orchestrated progression of technology advancement alongside legal, ethical and cultural progress. In particular, consideration of how humans establish trust and confidence in intelligent autonomous systems will likely govern their implementation. It will be essential that we have adequate insight into how such systems sense their environment, interpret this information, decide upon a course of action, execute that plan of action, monitor execution, respond to unexpected/unpredictable circumstances and deal with system failures.

Strategic personnel planning, or force structure models, that demonstrate explicitly how new technologies will change what is required and who (or what) might undertake such roles need to be developed. These models should comprise a Defence workforce where age, physical and cognitive profiles align with the demands of a more technologically complex environment. The adoption of biological monitors and predictive diagnostics tools to proactively manage health can be expected to help enable greater use of an ageing workforce.

Ultimately, for Defence, the challenge will be to decide what levels of machine autonomy are acceptable in what circumstances. System resilience and robustness under pressure must be a defining attribute of the delivery of information and automation in Defence.

Smart power

Growth in R&D expenditure by major Asian countries mirrors their overall economic growth, with R&D investment by Asian countries now surpassing that of Europe. Given innovation and the development of technical expertise are also enduring stimulants for economic growth, this trend is unlikely to reverse in the near term.

R&D expenditure is known to be strongly correlated to the quality of military capability 10 to 25 years later. While the US will continue to dominate military R&D investment, strong growth in R&D expenditure by Asian nations will see a narrowing of the gap in the quality of military equipment relative to Western countries.

Australia has established strong research links with the US, Europe, China, Japan, the Republic of Korea and India, and these research links are complemented by our deep engagement with the region in tertiary education. Through the resultant organisational and cultural links, Australia finds itself uniquely poised to leverage the investment by Asian and Western countries for our national benefit. With the backing of a strong knowledge economy, Australia could exercise "smart power" in the form of science diplomacy.

Implications for Defence

Australia's strongest research links are with the US and these deep and broad linkages will continue to serve our nation well into the future. However, many Asian countries have been investing in R&D heavily for the last 10 to 15 years, and they may soon reach the tipping point in realising this investment as competitive commercial and military capabilities.

The opportunity now exists for Australia's innovation system to partner with Asian nations capitalising on our close proximity, while also strengthening our leverage from collaborative Western R&D investment. This provides a platform for improving our already solid research links with Asian countries to our benefit and that of all our collaborative partners. In addition, Australia's international tertiary student enrolment provides an excellent means of building ongoing mutual understanding and social, cultural and business links.

What next?

Australian R&D capability could be utilised as a national strategic asset where, through collaboration, it can wield 'smart power'. Exercising this type of science diplomacy provides opportunities to build regional engagement and, ultimately, national prosperity and security.

Achieving positive national outcomes through the employment of smart power would require Australia to carefully calculate and manage the strategic value of our science, technology, engineering and mathematics (STEM) capabilities. Such a calculation should identify strategic STEM capabilities based on defence and national security needs, as well as academic/industrial/commercial investments that may deliver a national competitive edge.

It is through the careful planning and nurturing of our science, technology, engineering and mathematics capabilities that Australia could become a leading exponent of smart power.

Innovation enterprise

The 'global middle' comprises people with some disposable income to spend on durable and luxury items as well as experiences. Today, the global economy relies heavily on Western consumption. In 2035, the bulk of the global middle driving consumption will reside in Asian countries, especially China and India. This will result in big shifts in tastes, products, fashions, and designs. The global middle will also consist of people who are more effectively motivated intrinsically (social contact, intellectual stimulation, social recognition) rather than extrinsically (money). This generation of consumers is versed in harnessing the power and energy of the individual to make meaningful changes. New business models, offering customisation and personalisation, are emerging to meet these differing demands. In line with these new ideas and advertising to consumer groups, agile manufacturing technologies will enable tailoring of products for the consumer.

National boundaries are becoming less important in the commercial world and most nations will increasingly lose access to industrial surge capacity during times of national need. Few developed nations will be able to sustain mass-production manufacturing. This relaxation of boundaries and increasing propensity to off-shore manufacturing may in turn lead to concerns of provenance in supply chains. In addition, control of triple use (commercial, civilian and military) capabilities, such as logistics, surveillance and communications, will be ceded to multi-national compacts and commercial interests. Agile manufacturing will supplant many conventional manufacturing approaches whilst taking advantage of extant infrastructure as it provides greater flexibility for personalising products in an economically viable way. This may present Australia with better bargaining power in procuring customised capabilities that meet niche needs.

Launching Unmanned Aerial Vehicle in Afghanistan.

Implications for Defence

Defence will need to adapt to this new world where it does not have full control of its critical capabilities. Defence can be adaptable to future events by leveraging new business models. Value-add will be derived in innovation and design phases. Exploiting science and technology investment in emerging technologies can afford Defence greater negotiation power to influence the new commercial world. For example, agile manufacturing will revolutionise logistic systems from 'just in time' to 'built on demand' with improved efficiencies *in-situ* and supply chains and provision of better quality or fit-to-function solutions for warfighters. The requirement for Defence to maintain and protect long lines of supply and communication will be reduced but protection of sovereign capability and/or information will remain paramount.

What next?

Defence must determine how to harness the new 'sharing economy' business models. Agile manufacturing will fundamentally change the way Defence views capability innovation. Further, the way we source materials and manage supply and logistics will counteract some of the concerns with the protection of complex and congested supply chains. Agile manufacturing technologies will enable Defence to be responsive to rapid changes by an adaptive adversary.

Exploiting science and technology investment in emerging technologies can afford Defence greater negotiation power to influence the new commercial world. ◘

References

1 Commonwealth of Australia (2013) "Defence White Paper 2013", Department of Defence

2 Commonwealth of Australia (2013) "Strong and Secure: A Strategy for Australia's National Security", Department of the Prime Minister and Cabinet

3 Commonwealth of Australia (2012) "Australia in the Asian Century White Paper", Department of the Prime Minister and Cabinet, October

4 Hajkowicz, S.A., Cook, H. & Littleboy, A. (2012) "Our Future World: Global megatrends that will change the way we live", The 2012 Revision, CSIRO, Australia

5 MIT Technology Review (2013) "2013 Emerging Trends Report", Jason Pontin, editor-in-chief

6 Kaku, M. (1998) "Visions: How Science will Revolutionalize the 21st Century and Beyond", Oxford University Press, Oxford

7 Irvine, J.H. & Schwarzbach, S. (2011) "New Technologies and the World Ahead: The Top 20 Plus 5", The Futurist, May-June, Vol. 45, No. 3

8 Thurow, L.C. (1996) "The Future of Capitalism: How today's economic forces shape tomorrow's world" William Morrow, New York

9 United Nations (2013) "World Population Prospects: The 2012 Revision, Key Findings and Advance Tables", Working Paper No. ESA/P/WP.227, Department of Economic and Social Affairs, Population Division

10 Commonwealth of Australia (2010) "Australia to 2050: Future Challenges", Intergenerational Report, Attorney-General's Department, January

11 Commonwealth of Australia (2010) "Australia to 2050: Future Challenges", Intergenerational Report, Attorney-General's Department, January

12 World Population Trends 2012 from ‹http://www.prb.org/Publications/Datasheets/2012/world-population-data-sheet/fact-sheet-world-population.aspx›

13 United Nations (2013) "World Population Prospects: The 2012 Revision, Key Findings and Advance Tables", Working Paper No. ESA/P/WP.227, Department of Economic and Social Affairs, Population Division

14 United Nations (2013) "World Population Prospects: The 2012 Revision, Key Findings and Advance Tables", Working Paper No. ESA/P/WP.227, Department of Economic and Social Affairs, Population Division

15 United Nations (2012) "World Urbanization Prospects: The 2011 Revision, Highlights", Department of Economic and Social Affairs, Population Division

16 Menon, M. (2011) "Asia Pacific Market Insights", Frost & Sullivan's commentary on the effect of Mega Trends across industries, addressing opportunities, best practices, and major events. Viewed on 4 February, ‹http://frost-apac.com/download/megatrends.pdf ›

17 Anderson, K. & Strutt, A. (2012) "Agriculture and Food Security in Asia by 2030", ADBI Working Paper 368, Tokyo: Asian Development Bank Institute

18 See for example BP (2014) "BP Energy Outlook 2035", January, viewed on 2 Feb 2014, ‹http://www.bp.com/content/dam/bp/pdf/Energy-economics/Energy-Outlook/Energy_Outlook_2035_booklet.pdf ›

19 See for example Lovins, A. A. (2012) "Farewell to Fossil Fuels: Answering the Energy Challenge", Foreign Affairs, March / April 2012, viewed on 2 February 2014, ‹http://www.rmi.org/Knowledge-Center/Library/2012-01_FarewellToFossilFuels›, Rocky Mountain Institute (2012) "Net Energy Metering, Zero Net Energy ant the Distributed Energy Resource Future: Adapting Electricity Utility Business Models for the 21st Century", March, viewed on 2 February 2014, ‹http://www.rmi.org/Content/Files/RMI_PGE_NEM_ZNE_DER_Adapting_Utility_Business_Models_for_the_21st_Century.pdf ›, Rocky Mountain Institute (2012) "Guide to Building the Case for Deep Energy Retrofits", September, viewed on 2 February 2014, ‹http://www.rmi.org/Content/Files/RMI_Retrofit_Guide_BuildingTheCase_1.1.pdf ›

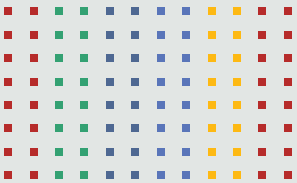
20 Commonwealth of Australia (2010) "Australian Social Trends June 2010", Australian Bureau of Statistics, Catalogue no. 4102.0, June

21 Vespignani, A. (2010) "Complex networks: The fragility of interdependency", Nature 464, pp. 984-985

22 Vespignani, A. (2010) "Complex networks: The fragility of interdependency", Nature 464, pp. 984-985

23 Buldyrev, S. V., Parshani, R., Paul, G., Stanley, H. E. & Havlin, S. (2010) "Catastrophic cascade of failures in interdependent networks", Nature 464, pp.1025-1028

24 Deloitte Access Economics (2011) "Long term economic and demographic projections", Annex H of the Australian Defence Force Posture Review, 24 November



25 Commonwealth of Australia (2010) “Australia to 2050: Future Challenges”, Intergenerational Report, Attorney-General’s Department, January

26 Commonwealth of Australia (2012) “Australia in the Asian Century White Paper”, Department of the Prime Minister and Cabinet ,October

27 International Labour Organization (2013) “Global Employment Trends for Youth 2013: A generation at risk”, International Labour Office, Geneva

28 Ablett, J. & Erdmann, A. (2013) “Strategy, scenarios, and the global shift in defense power”, McKinsey and Company Publication, April

29 Dobbs, R., Remes, J., Manyika, J., Roxburgh, C., Smit, S. & Schaer, F. (2012) “Urban world: Cities and the rise of the consuming class”, McKinsey Global Institute, June

30 Commonwealth of Australia (2012) “Australia in the Asian Century White Paper”, Department of the Prime Minister and Cabinet, October

31 Hajkowicz, S.A., Cook, H. & Littleboy, A. (2012) “Our Future World: Global megatrends that will change the way we live”, The 2012 Revision, CSIRO, Australia

32 Commonwealth of Australia (2013) “Australian Innovation System Report”, Department of Industry, Innovation Research, July

33 Commonwealth of Australia (2012) “Health of Australian Science”, Office of the Chief Scientist, May

34 Batelle (2013) “2014 Global R&D Funding Forecast”, R&D Magazine, December

35 Kydland, F. & Prescott, E. (1982) “Time to build and aggregate fluctuations”, Econometrica 50, pp. 1345-1371

36 Ablett, J. & Erdmann, A. (2013) “Strategy, scenarios, and the global shift in defense power”, McKinsey and Company Publication, April

37 Batelle (2013) “2014 Global R&D Funding Forecast”, R&D Magazine, December

38 Middleton, A., Bowns, S., Hartley, K. & Reid, J. (2006) “The Effect of Defence R&D on Military Equipment Quality”, Defence and Peace Economics, Vol. 17(2), April, pp. 117–139

39 Commonwealth of Australia (2013) “Australian Innovation System Report”, Department of Industry, Innovation Research, July

40 Watson, R. (2010) “Future Files: A Brief History of the Next 50 Years”, Nicholas Brealey Publishing, London

41 Ash, K. (2013) “Australia Horizon Scan”, Naval Surface Warfare Center, Dahlgren Division, NAVSEA

42 OECD (2013) “OECD Science, Technology and Industry Scoreboard 2013”, OECD Publishing, viewed on 4 February 2014, ‹http://dx.doi.org/10.1787/sti_scoreboard-2013-en›

43 Ash, K. (2013) “Australia Horizon Scan”, Naval Surface Warfare Center, Dahlgren Division, NAVSEA

44 Commonwealth of Australia (2012) “Australia in the Asian Century White Paper”, Department of the Prime Minister and Cabinet, October

45 OECD (2013) “OECD Science, Technology and Industry Scoreboard 2013”, OECD Publishing, viewed on 4 February 2014, ‹http://dx.doi.org/10.1787/sti_scoreboard-2013-en›

46 Maslen, G. (2014) “China still the number one source country”, University World News, Issue No: 305, January, viewed on 6 February 2014, ‹http://www.universityworldnews.com/article.php?story=20140130150720668›

47 OECD (2013) “OECD Science, Technology and Industry Scoreboard 2013”, OECD Publishing, viewed on 4 February 2014, ‹http://dx.doi.org/10.1787/sti_scoreboard-2013-en›

48 Commonwealth of Australia (2013) “Australian Innovation System Report”, Department of Industry, Innovation Research, July

49 Commonwealth of Australia (2013) “Australian Innovation System Report”, Department of Industry, Innovation Research, July

50 European Union Institute for Security Studies (2012) “Global trends 2030 – Citizens in an interconnected and polycentric world”, European Strategy and Policy Analysis System (ESPAS), Paris, March

51 Kharas, H. (2010) “The Emerging Middle Class in Developing Countries”, OECD Development Centre, Global Development Outlook, Working Paper No. 285, January

52 Li, C. (ed) (2010) “China's Emerging Middle Class: Beyond Economic Transformation Paperback”, Brookings Institution Press, November, 396 pages

53 Kharas, H. (2010) “The Emerging Middle Class in Developing Countries”, OECD Development Centre, Global Development Outlook, Working Paper No. 285, January

54 Court, D. & Narasimhan, L. (2010) “Capturing the world’s emerging middle class”, McKinsey Quarterly, July, viewed on 2 Feb 2014, ‹http://www.mckinsey.com/insights/consumer_and_retail/capturing_the_worlds_emerging_middle_class›

55 Messieh, N. (2013) “5 Ways To Harness The Power Of The Crowd” August, viewed on 2 Feb 2014, ‹http://www.makeuseof.com/tag/5-ways-to-harness-the-power-of-the-crowd›

56 Credit Suisse (2013) “Global Wealth Report 2013”, Zurich: Credit Suisse, October, viewed on 2 Feb 2014, ‹https://publications.credit-suisse.com/tasks/render/file/?fileID=BCDB1364-A105-0560-1332EC9100FF5C83›

57 ‹http://en.wikipedia.org/wiki/Billionaire›

58 Hajkowicz, S.A., Cook, H. & Littleboy, A. (2012) “Our Future World: Global megatrends that will change the way we live”, The 2012 Revision, CSIRO, Australia

59 Taylor, C. (2012) “As consumer power goes viral, company branding quakes”, Reuters, January, viewed on 2 Feb 2014, ‹http://www.reuters.com/article/2012/01/06/us-usa-companies-backlash-idUSTRE80424T20120106›

60 Carmel, E (2013) “Predicting the Growth of Crowdsourcing”, September, viewed on 2 Feb 2014, ‹http://www.crowdsourcing.org/editorial/predicting-the-growth-of-crowdsourcing/28548›

61 Oliver, K., Moeller, L.H. & Lakenan, W. (2004) “Smart Customization: Profitable Growth Through Tailored Business Streams”, strategy+business, Spring, Issue 34, Booz & Company, viewed on 2 Feb 2014, ‹http://www.strategy-business.com/article/04104?pg=all›

62 Barnett, C. (2013) “The Crowdfunder's Guide To General Solicitation And Title II Of The JOBS Act”, Forbes, September, viewed on 2 Feb 2014, ‹http://www.forbes.com/sites/chancebarnett/2013/09/23/the-crowdfunders-guide-to-general-solicitation-title-ii-of-the-jobs-act›

63 Space Foundation (2013) “The Space Report: The Authoritative Guide to Global Space Activity – Overview”, Colorado Springs, CO, USA

64 Lichterman, J. & Woodall, B. (2013) “In largest-ever U.S. city bankruptcy, cuts coming for Detroit creditors, retirees”, Reuters, December, viewed on 2 February 2014, ‹http://www.reuters.com/article/2013/12/03/us-usa-detroit-bankruptcy-judge-idUSBRE9B20PZ20131203›

Bibliography

Cook, H., Hajkowicz, S., King, S. & Cox, F. (2013) "Elements in Everything: Current profile and future trends for the Australian chemicals and plastics industry", CSIRO, Australia

Gore, A. (2013) "The Future: Six Drivers of Global Change", Random House, New York

Government of Canada, (2014) "The Future Security Environment 2013-2040," National Defence, Chief Force Development, Ottawa

Hajkowicz, S.A., Cook, H. & Boughen, N. (2013) "The Future of Tourism in Queensland. Megatrends creating opportunities and challenges over the coming twenty years", CSIRO, Australia

Hajkowicz, S.A., Cook, H., Wilhelmseder, L. & Boughen, N., (2013) "The Future of Australian Sport: Megatrends shaping the sports sector over coming decades", A Consultancy Report for the Australian Sports Commission, CSIRO, Australia

Mason, B. & Wood, D. (eds) (2013) "Future Proofing Australia: The Right Answers for Our Future", Melbourne University Publishing, Carlton

Ministry of Defence (2010) "Global Strategic Themes - Out to 2040", 4th Edition, Development, Concepts and Doctrine Centre, United Kingdom

National Intelligence Council (2012) "Global Trends 2030: Alternative Worlds", Office of the Director of National Intelligence, U.S.A, December

Pettigrew, A.G. (2012) "Australia's Position in the World of Science, Technology & Innovation", Occasional Paper Series, Issue 2, Office of the Chief Scientist, Canberra

Silberglitt, R., Antón, P.S., Howell, D.R. & Wong, A. (2006) "The Global Technology Revolution 2020, In-Depth Analyses: Bio/Nano/Materials/ Information Trends, Drivers, Barriers, and Social Implications", RAND TR-303-NIC, 314 pages

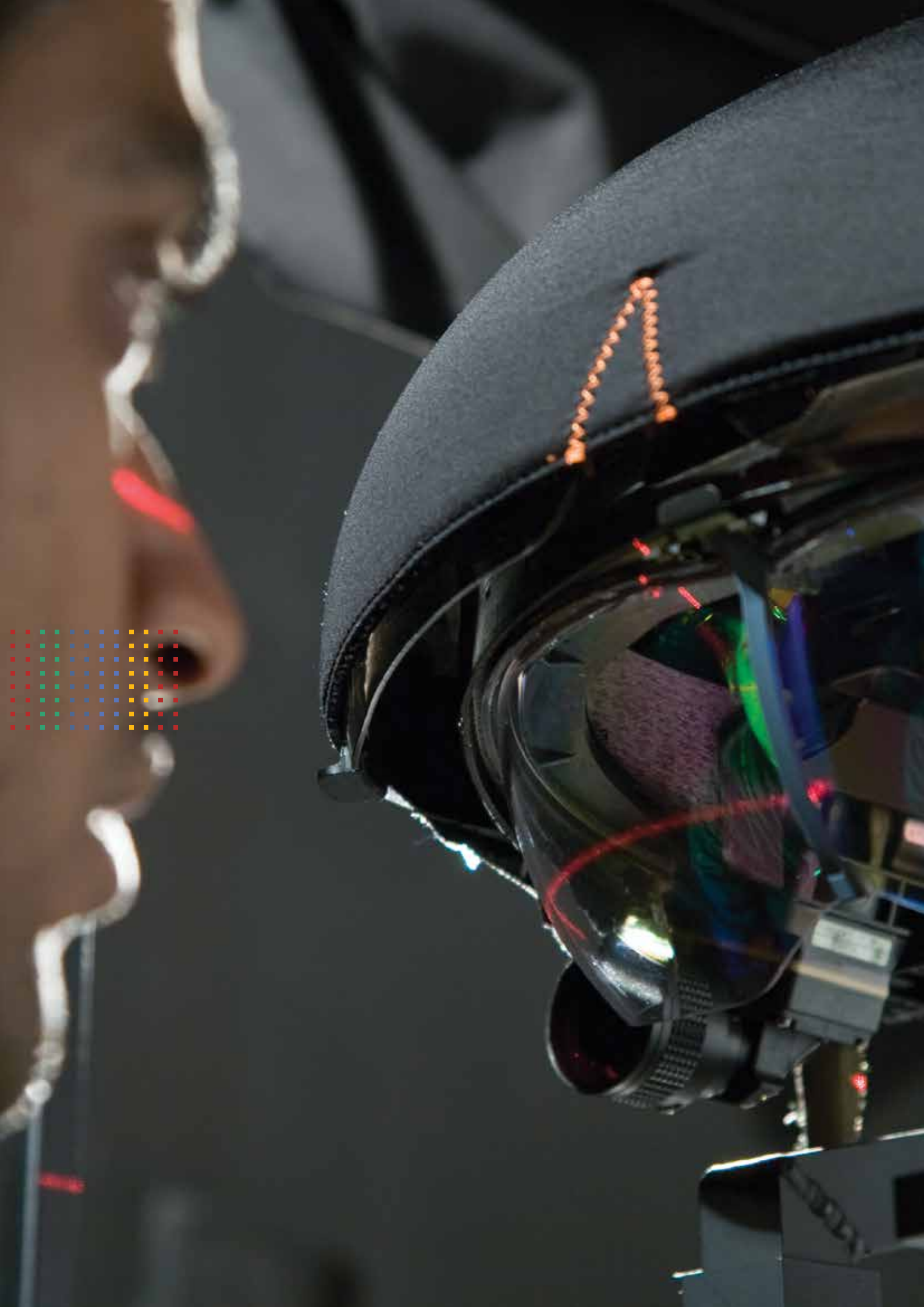
Singh, S. (2012) "New Mega Trends: Implications for our Future Lives", Palgrave Macmillan, London

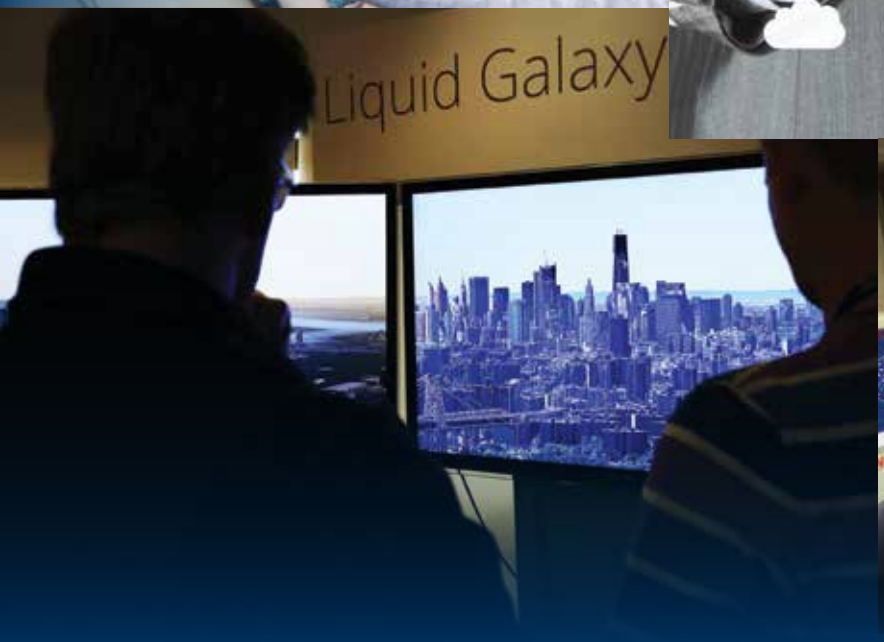
Watson, R. (2010) "Future Files: A Brief History of the Next 50 Years", Nicholas Brealey Publishing, London

Contacts

Chief Joint and Operations Analysis Division
Phone: +61 3 9626 7700
CJOAD@dsto.defence.gov.au

Group Leader Land Organisation Management Science
Phone: +61 2 6128 6402
joanne.nicholson@dsto.defence.gov.au





For more information on DSTO visit
www.dsto.defence.gov.au
Download the free DSTO App

Available on the App Store

Google play