POLICY BRIEF

Emerging Technologies and Military Capability

S. RAJARATNAM SCHOOL
OF INTERNATIONAL STUDIES
A Graduate School of Nanyang Technological University

Dr Andrew D. James
November 2013

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Abstract

"Emerging technologies" are the subject of considerable interest to academics and practitioners not only in the field of military capability and international security but also in the fields of economics and business. Emerging technologies are said to have the potential to change "the rules of the game" whether that "game" is the balance of military power between security actors or the balance of competitive advantage in a market between incumbent companies and new entrants.

Consequently, visions of the military future almost always have a strong technological element. This paper examines the nature of emerging technologies, their implications for military capability and the challenges that they pose to the acquisition system. The paper emphasises that their emergent nature means that emerging technologies are characterised by considerable uncertainty: will their apparent technological promise be fulfilled? How long will it take to develop them to a sufficient state of maturity that they have practical application (and how much will that cost?) How might they be most effectively utilised (if at all)? At its core, the paper stresses that it is a potentially long and uncertain journey from the emergence of a new technology to its use in a fielded weapons system.

Such issues are important because new technologies have the potential to change the environment in which militaries operate and a radical new technology can change the balance of power or create new forms of insecurity. New technologies can change military doctrine and the way that war fighting is conducted. New technologies can make existing defence systems obsolete or provide new and more effective military capability. By and large, attention has tended to focus on new-to-the-world technologies yet novel combinations of existing and mature technologies can also have profound military implications.

At the heart of the paper is a consideration of the link between emerging technologies and military capabilities and the importance of institutional factors and the acquisition system in determining the speed of adoption of emerging technologies. It is argued that technological and economic change means that this is an increasingly important issue. Defence is playing a declining role as a sponsor of advanced technologies and will become a follower rather than a leader in many (most) areas of technology. Consequently, most emerging technologies will arise from scientific, technological and innovative activity taking place in civilian sectors, small firms and universities *world-wide*. In the future, the defence innovation process will need to place more emphasis on the timely identification and effective exploitation of emerging technological knowledge wherever it resides. The future of defence technology policy is likely to be in building absorptive capacity and agility by (i) developing effective search mechanisms to identify potentially important emerging technologies and their sources, (ii) building effective partnerships with (potentially) non-traditional suppliers of such technological capabilities, and(iii) finding means for the agile exploitation of those emerging technologies to military advantage.

Introduction

"Emerging technologies" is the subject of considerable interest to academics and practitioners not only in the field of international security but also in the fields of economics and business. Emerging technologies are said to have the potential to change "the rules of the game" whether that "game" is the balance of military power between security actors or the balance of competitive advantage in a market between incumbent companies and new entrants.

By "emerging technologies", this paper will mean new technologies that are at an early stage in their development. Their emergent nature means that they are characterised by considerable uncertainty: will their apparent technological promise be fulfilled? How long will it take to develop them to reach a sufficient state of maturity that they have practical application (and how much will that cost?). How might they be most profitability utilised? Examples of the effects of the emergence of new technologies on business are many and varied. Take the dramatic fall of Eastman Kodak. The dominant company in the photographic industry for a century was swept away in a matter of a decade by the emergence of digital imaging technology and the capacity of new entrants to exploit that technology in new products. Emerging technologies have had similar impacts on military power. During the Second World War, the emergence of radar had a dramatic impact not least in the defence of the U.K. during the Battle of Britain and the conduct of anti-submarine warfare in the North Atlantic.[1] During the Cold War, emerging computer technologies, electronic component technologies (not least semiconductors) and propulsion technologies – all sponsored at the time by the military – each had significant impacts on the performance of Cold War weapons systems and perceptions of the Cold War balance of military power.[2]

The aim of this paper is to examine the nature of emerging technologies and their potential impact upon military capability. The paper is structured as follows: Section 2 provides some examples of emerging technologies that have been identified as having potential implications for military capability in the future. This section also discusses why emerging technologies are of concern in the military context and the threats and opportunities that they can pose. Section 3 defines "emerging technologies" and makes the distinction between technologies, weapon systems and, technologies and innovation. Section 4 introduces the notion of the "technology life cycle" to explain the nature of emerging technologies. Section 5 discusses a key feature of emerging technologies, namely uncertainty, and the reasons why it is difficult to make accurate ex ante assessments of the rate and timing of a technology's development. Section 6 considers the link between emerging technologies and military capabilities and the importance of institutional factors and the acquisition system in determining the speed of adoption of emerging technologies. Section 7 considers the sources of emerging technologies of military relevance in a global technological environment characterised by "Joy's Law" (i.e. "No matter who you are, the smart people always work for someone else"). Section 8 seeks to identify some implications for the Asia Pacific. Section 9 provides a conclusion.

Emerging Technologies and the Military

Visions of the military future almost always have a strong technological element. A review of futures studies conducted by the likes of the UK MOD Defence Concepts and Doctrine Centre (DCDC)'s Strategic Trends Programme, the U.S. National Intelligence Council Global Trends Program, the French Ministry of Defence and the European Defence Agency shows that emerging technologies feature prominently.[3] They identify emerging technologies such as: (i) autonomous systems and robotics, (ii) swarming autonomous micro aerial vehicles, (iii) developments in nanotechnology sensors, (iv) cyberspace, (v) directed energy weapons, among many others. Advances in microsystems, nanotechnology, unmanned systems, communications and sensors, digital technology, bio and material sciences, energy and power

[1] On radar and the air defence of the UK see the excellent PhD thesis by Phillip Judkins (2007) *Making Vision into Power: Britain's Acquisition of the World's First Radar-based Integrated Air Defence System 1935-1941*, PhD thesis, Defence College of Management and Technology, Cranfield University.
[2] For more details, see Andrew D James (2007) "Science and technology policy and international security", in Brian Rappert (ed) (2007) *Technology and Security: Governing Threats in the New Millennium*, Palgrave MacMillan: New York and Houndsmill.
[3] James, A.D and Teichler, T. (forthcoming) "Defence and security: new issues and impacts", *Foresight*.

technologies and neuro-technologies are all identified as likely to have important applications in the defence sector. Cyber security and cyber warfare will grow ever more significant. The UK MOD DCDC's analysis is typical:

> "Trend analysis indicates that the most substantial technological developments are likely to be in the areas of: (i) ICT, (ii) sensor/network technology, (iii) behavioural and cognitive science, (iv) biotechnology, (v) materials,(vi) and the production, (vii) storage and (viii) distribution of energy. Advances in nanotechnologies will underpin many breakthroughs. Developments in individual areas are likely to be evolutionary, but where disciplines interact, such as in the combination of cognitive science and ICT to produce advanced decision-support tools, developments may be revolutionary, resulting in the greatest opportunities for a novel or breakthrough application….[S]ome [emerging technologies] may have catastrophic effects or present potential threats, perhaps through perverse applications, such as the use of genetic engineering to produce designer bio-weapons" (pp.135-136).

Emerging technologies matter to the military because new technologies can present a threat or opportunity and yet they are veiled in uncertainty. The military understands the potential of new technologies but – like its counterparts in civilian business strategy – the uncertainty that characterises emerging technologies mean that they cannot know which emerging technologies mature to have profound impacts, how long that maturation will take nor the technological trajectory. Most emerging technologies represent incremental improvements to what went before and enhance the competencies of the military along dimensions that they have traditionally valued. This kind of technological development presents relatively few challenges to the military, although their insertion into existing platforms can be difficult (as we shall see). In contrast, it is new technologies that are radical, competence destroying and create new sources of military advantage along dimensions not traditionally valued or poorly understood by the military that tend to be the focus of attention and concern.

Fundamentally, these types of new technologies can change the environment in which military forces operate. A radical new technology can change the balance of power or create new forms of insecurity. The most dramatic illustration of the impact of new technology was the Allied development of the atomic and hydrogen bombs during the Second World War and the subsequent development of similar capability by the Soviet Union. In turn, the development of inertial navigation technologies added the prospect of accuracy to devastating lethality.

New technologies can redefine the way that warfare is conducted or create new types of warfare. Technology and military doctrine are closely coupled and interdependent.[4] Blitzkrieg, the Air-Land Battle and Carrier Strike are but the examples of how new technologies combined with organisational change led to new ways of warfare.[5] The internet and its widespread application has created the possibility of a new form of warfare – cyber warfare – that was hardly imaginable 20 years ago.

Equally, the significance of an emerging technology also depends in part on whether it is competence enhancing or competence destroying. An emerging technology that undermines existing training, equipment, doctrine and so forth will have a more dramatic impact on the military than one that complements or enhances existing military competencies. New technologies can render existing defence systems obsolete. Cavalry on the Western Front is but one example (although it was only the carnage of battle that brought this home to military planners).

At the same time, a new technology can provide new and more effective military capability. Precision munitions, not least the use of GPS technology, is a good example. Increased accuracy has led to a reduction in the number of aircraft required to attack targets and the substitution of heavy bomber for lighter fighter bombers.[6]

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[4] Alic, J.A. (2007) *Trillions for Military Technology: How the Pentagon Innovates and Why it Costs So Much*, Palgrave MacMillan: New York and Houndsmill.
[5] See Williamson, W. and Murray, A.R. (eds.) (1996) *Military Innovation in the Inter-War Period*, Cambridge University Press: Cambridge
[6] Alic (2007) *op cit*.

By and large, attention has tended to focus on radical new-to-the-world technologies yet novel combinations of existing and mature technologies can also have profound military implications. Schumpeterian thinking emphasises that innovation can be new combinations of existing technologies and stresses the potential significance of combining existing technologies in a new use. The DCDC Strategic Trends study identifies the rapid asymmetric insertion and exploitation of commercial technologies as a significant concern. Indeed, the experience of Iraq and Afghanistan provides graphic illustrations of how such tactics can have devastating effects. The contrast between the rates of combinatorial innovation of this kind has posed challenges to the traditional defence acquisition process. In the future, such developments may present ever greater challenges to the traditional, long-term requirement and acquisition cycles.[7]

Defining Emerging Technologies

Before going any further, it is important to define what is – and what is not – meant by "emerging technologies". The U.K.'s Defence Technology Plan defines emerging technologies as follows: "Emerging technologies can be characterised as: immature technologies in the early proof-of-principle stages; more mature technologies but where a novel defence application has been identified". While this definition appears clear and straightforward (and this paper will use it), it is the case that a feature of much of the discussion of emerging technologies is a lack of clarity as to the subject of analysis.

"Emerging" is used variously to examine technologies that analysts regard as potentially emerging in the far future (e.g. the latest U.K. MOD DCDC programme report looks out to 2040 and consciously examines what technological developments *may* occur). In contrast, "emerging" is sometimes used to describe technologies that have reached a stage that we know that they *will* find application in a weapon system in the near future (e.g. many of the "emerging" IT technologies discussed by Bruce Berkowitz in his 2003 book are now in military service at least with the United States military[8]). Sometimes analysts conflate the far future and the soon to be fielded as "emerging technologies" giving the impression to the unwary that (true) emerging technologies on the technological far horizon are as certain to be fielded as those in late stage development. This raises important questions about timing that are critical to discussions about emerging technologies. It also raises issues about uncertainty. Both issues will be discussed later in this paper.

A further source of ambiguity in discussions about emerging technologies is what is meant by "technologies". Technologies can be defined as "The ensemble of theoretical and practical knowledge, know-how, skills and artefacts that are used... to develop, produce and deliver... products and services"[9]). This definition is concerned with technology and business but it holds equally for military technology. Military technology combines "theoretical and practical knowledge" – some may be science based but much will be engineering knowledge, including "know-how and skills" – individual and collective knowledge that arises within defence through "learning by doing", team working, culture and so forth and "artefacts" – tangible assets such as capital equipment, manufacturing facilities and so forth. It is worth noting that following this definition much of the core "technology" that underpins defence is intangible and human.

There is an important distinction here that is sometimes missed by military analysts of emerging technologies (business analysts miss this too). The distinction is between technologies and products/services (in the case of the military, we mean weapons, their delivery systems and the infrastructure that supports military capability). Technologies underpin weapon systems but are distinct from them. Militaries want "capability", not technologies *per se*. Consequently, how emerging technologies and other factors are combined into military capability should be the critical consideration not the emerging technologies themselves (this is an important point that we shall return to later).

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[7] Development, Concepts and Doctrine Centre (DCDC) [UK], *Global Strategic Trends: Out to 2040*, Fourth Edition, Ministry of Defence: London.
[8] Bruce Berkowitz (2003) *The New Face of War: How War will be Fought in the 21st Century*, The Free Press: New York.
[9] Burgelman, R.A. and Rosenbloom, R.S. (1989) "Technology strategy: an evolutionary process perspective" *Research on Technological Innovation, Management and Policy*, vol.4.

Equally, new or improved classes of weapon rarely (if ever) comprise only new ("emerging") technologies but instead combine new technologies with mature technologies. Schumpeterian thinking emphasises that innovation can be new combinations of existing technologies – existing technologies in a new use. Innovation that produces modern weapons systems is increasingly based on the dynamic recombination of generic technologies which are often information technologies.[10]

The decision to invest in an emerging technology in the hope of military capability advantage depends on very many factors not least the perception of the threat environment. The Cold War was different to today. World Wars are different to regional conflicts. The military needs of forces in Iraq and now Afghanistan have brought home the fact that emerging technologies are only of military significance if they can be matured and fielded quickly enough to make a difference to current combat operations. Investments in emerging technologies that may only have application in 30 years time and are characterised by uncertainty have always had lower priority. Constrained defence budgets in the U.K., Europe and the United States mean that this is likely to be even more the case in the future. Indeed, this speaks to the need for greater agility in the defence acquisition process. The military technological innovation timescale that emerged during the Cold War means that development times of 20 years for major weapon systems became the norm. New designs of Improvised Explosive Devices (IEDs) seem to appear in Afghanistan on a monthly basis. Changes in cyber threats can occur just as quickly. This requires reform of the defence innovation process to promote greater agility and reduce time-to-fielding of new equipment.

Another important point needs to be made and that is the danger of analysis of emerging technologies degenerating into some form of technological determinism. The idea that emergence of a new technology leads inevitably to change and that technology is necessary and sufficient to drive innovation in military capability has been widely discredited by those who study innovation. The study of military innovation emphasises the critical role of political and bureaucratic politics among both military and civilian actors in selecting (or not selecting) particular technologies.[11] Equally, it emphasises the relationship between technology and doctrine.[12] Grissom summarises the literature on Social Shaping of Technology and its emphasis on the nature of technologies as:

> "ultimately ideas that are shaped by discourse and competition with different views on the potential of a given technology… these interest groups (such as research teams, policymakers and investors) vie to superimpose their own vision on a developing technology by building a coalition around their vision, engaging in bureaucratic manoeuvres to exclude other groups, and ensuring that important design and engineering choices reflect their vision for the technology".[13]

In short, an emerging technology, its funding, trajectory and adoption in use is shaped by a variety of actors. There is nothing "inevitable" about the trajectory of a new technology or how it will (or will not) be used. This insight is important as we turn to consider the technology life cycle.

Emerging Technologies and the Technology Life Cycle

A clear understanding of what we mean by "emerging technologies" matters since there is a danger that those discussing the military implications of such technologies may find that they are talking at cross-purposes about different objects of analysis, over different timescales and so forth. Those who study technological change think in terms of the technology life cycle (TLC).[14] This S-curve is illustrated in Figure 1.[15] Note that the TLC is divided into three stages distinguishing between emerging,

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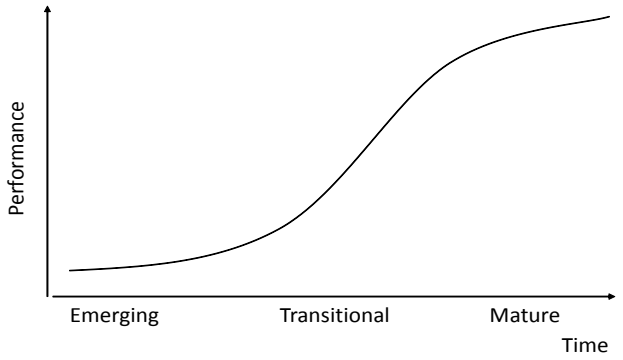
[10] Hasik, J. (2008) *Arms and Innovation: Entrepreneurship and Alliances in the twenty First Century Defense Industry*, University of Chicago Press: Chicago.
[11] Grissom, A. (2006) "The future of military innovation studies", *Journal of Strategic Studies*, 29 (5): 905-934.
[12] Alic *op cit.*
[13] Grissom (2006) *op cit.*
[14] The analogy of biological life is popular in the academic business and innovation community and the technology life cycle (and product life cycle which I will also mention) should not be confused with the R&D lifecycle, product life cycle management and so fort*h*.
[15] Technology life cycle and product life cycle are both presented as logistic (S) curves

transitional and mature technologies and is mapped along two dimensions: time and performance. In many respects, this is covering similar ground to the idea of Technology Readiness Levels used by NASA, the European Space Agency and in defence.[16]

Figure 1: Emerging technologies and the technology life cycle



The TLC begins with the emerging phase. An emerging technology is characterised by its relatively poor and uncertain performance. The technology is at the proof of concept stage, characterised by high levels of technological uncertainty and uncertainty as to the feasibility of its application in military systems. The emerging stage may involve the transition from scientific research to applied research and the observation of the essential characteristics of the technology. Analysis and experimentation will likely take place to ensure proof of concept. At the emerging stage, the technology is a long way from providing military capability in a fielded system (TRL 1-3). During the transitional stage, (roughly TRL 4-5) the technology is subject to testing through prototyping and other activities. At this stage, the technology will likely be tested in a relevant and realistic environment to judge its potential performance. At the mature stage, the technology's performance characteristics are well understood. The technical uncertainties that characterised the earlier stages have been reduced and efforts focus on questions of design and integration into military systems prior to the production phase for a new military system or the insertion of the new technology into an upgrade of an existing system.

The issues of what we mean by "performance" and "time" are worthy of further examination. The TLC has time as its X-axis and it is clear that the timescale for a new technology can vary greatly depending on its technical characteristics, complexity, the state of scientific and engineering knowledge as well as level of funding available for that technology and the priority it is given within the defence acquisition community of an individual country. Equally, it is clear that many of those technologies labeled by analysts and advocates as "emerging" may – using the TLC – actually be transitional or even mature.

The Y-axis of the TLC is performance. This should also be examined carefully although the unit of performance is frequently left unexplained by academics using the TLC approach. In computing, performance may be memory size or clock speed. In the military context, performance may be speed, lethality or precision or perhaps some combination of performance measures. In the modern security environment, what constitutes the key performance measure is increasingly open to debate and no longer straightforward. Performance is no longer about only technological trajectories but also about whether technologically possible weapons are suitable on political and ethical grounds.

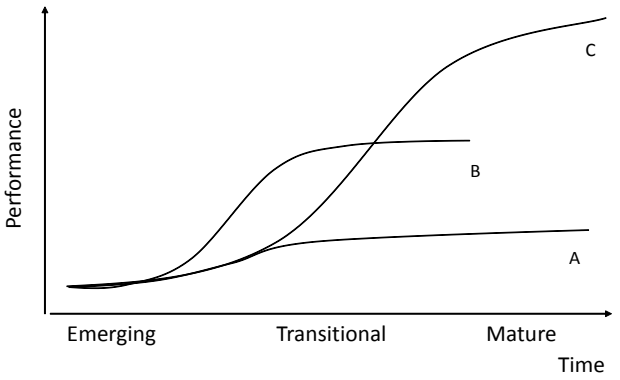
Uncertainty and Emerging Technologies

The uncertainty that surrounds emerging technologies has been mentioned at various points in this paper and deserves further discussion. Uncertainty is a key characteristic of technological change and stems from the difficulties of ex ante assessment of the rate and timing of a technology's development. Failed predictions about technological developments are legion. Bill Gates is said to have said about computer memory that "640k ought to be enough for anybody".[17] A British Training manual in 1907 stated: "It must be accepted as a principle that the rifle, effective as it is, cannot replace the effect produced by the speed of the horse, the magnetism of the charge and the terror of cold steel". Marshal Ferdinand Foch was reported as saying in 1911:"Airplanes are interesting toys but of no military value".[18]

[16] For a definition of Technology Readiness Levels see http://esto.nasa.gov/files/trl_definitions.pdf
[17] He says he never said this.
[18] Adam Simons, "The art of being wrong: failed predictions" http://urbantimes.co/2012/02/being-wrong-failed-predictions/ (last downloaded 23 January 2013)

Why are emerging technologies characterised by uncertainty? Figure 2 describes three S-curves for the life cycles of three technologies. They illustrate that uncertainty may arise because the technology is radical; the technology is early in its life cycle but also because of the increasingly amorphous nature of security threats.[19]

Figure 2: Emerging technologies and the nature of technological innovation



The S-curve labelled (A) emphasises that some technologies may fail to deliver on the early performance claims of their advocates. They may fail to deliver because engineering and technological challenges arise that are difficult to overcome without excessive time or other resources. Equally, they may reflect a "conspiracy of optimism" in which those who have a vested interest in a particular technology over-sell its military potential. Academic grant holders and researchers in government defence research laboratories may boost the technology to ensure their own funding. Entrepreneurs may claim military relevance to access "free" defence funding for early stage technology development. Experts in think tanks may over-sell the potential of a technology to sell books or access funding for workshops. Failure is normal, natural and desirable. This may be an uncomfortable truth for officials in a resource-constrained environment. DARPA's "success" was its ability to allow space for "failure" – a number of significant DARPA programmes (including UAVs) were the outcome of returning to a "failed" project.

The S-curve labelled (B) illustrates a situation where a technology is superseded by other technologies that are better or cheaper or faster to develop. Since it is impossible to forecast the eventual outcomes of emerging technologies, and since few (if any) countries have the resources to pursue all emerging technologies, this raises important strategic questions: should a country seek to pick a winner? Should it lag behind and hope that an ally invests in the technology, and is subsequently willing to transfer that technology, or does a country seek to follow all of them but develop processes that allow it to know when to stop when initial expectations prove unfounded? A small country may choose to lag behind and simply invest in adsorptive capacity (to access commercial technologies) and/or a limited range of distinctive capabilities that allows it to enter into cooperative arrangements with other countries. This suggests that investments should be in scanning the environment and in absorptive capacity rather than seeking to sponsor new technology development which speaks to an "open innovation strategy" (we will discuss this later).

S-curve (C) emphasises that only some technologies will reach the stage that they are deemed sufficiently mature that they may be considered for transition into new military capability. The design dilemma faced by the defence acquisition community is the trade-off between the costs of designing in emerging technologies against the benefits. Advocates of the emerging technologies understandably focus on their benefits but the costs are non-trivial. Those costs include those related to the uncertainties surrounding any emerging technology (will it work, at what cost and when?); the disruption to established military ways of operating (including doctrine); and the costs of substituting the new weapons for existing weapons. The fielding of new technologies in weapons systems is a function of the weapons development process and the procurement process of individual governments. An emerging technology may move along a development trajectory but never be translated into a fielded weapon.

Emerging Technologies and Military Capability

There is an understandable tendency for those who analyse emerging technologies to focus on those technologies. However, military innovation is about more

[19] Hasik, *op cit*.

than emerging technologies and there is a load road from the emergence of a technology to its having an impact on military capability.

An important point here is that the knowledge that underpinned these emerging technologies rarely resided in the military of a single country. The United Kingdom was not the only country to possess the knowledge that underpinned the emergence of radar. The United States was not the only country during the Cold War to possess semiconductor technologies. The military-scientific-industrial establishments of each country made decisions to prioritise the development of certain technologies for certain applications. The pace of application varied in part as a consequence of the ability of the military procurement process to pull the technologies through into fielded weapons.

In short, military innovation is about more than an emerging technology. We have already noted that while technologies may underpin weapons systems, they are distinct from them. The distinction is between technologies and products/services (in the case of the military, we mean weapons, their delivery systems and the infrastructure that supports military capability). Militaries want "capability", not technologies *per se*. Consequently, how emerging technologies and other factors are combined into military capability should be the critical consideration not the emerging technologies themselves.

However, the idea that military capability can be reduced to the fielding of weapon systems with superior technology is plainly wrong (although in the eyes of much of the world this Cold War mindset has characterised aspects of U.S. thinking with disastrous consequences, not least in Afghanistan). History shows that improving military effectiveness may require complementary organisational and doctrinal innovation.[20] For example, German Blitzkrieg was a military innovation that combined these with organisational and doctrinal innovations. Indeed, it has been argued that the whole issue of emerging technologies would be better thought of in terms of the innovative and emerging "uses" for existing technologies (it will be recalled that this point is made in the U.K. MOD's Defence Technology Plan). Recent insurgencies prove that a 100 year old rifle is as effective as a modern equivalent when used effectively and IED designs do not need to evolve that much to remain devastatingly effective.[21]

The procurement process can also have an important part to play in the adoption of an emerging technology. The responsive of the procurement process to new technologies has always been an important concern and is becoming more in the face of the twin forces of budget constraints (at least in Europe and the United States) and rapid technological change. The defence acquisition process has always faced the challenge that it generates more ideas and potential new technologies than it can possibly transfer into new weapons and other military equipment. This raises the matter of the so-called "Valley of Death" – the situation where R&D supports the development of an emerging technology only for that new technology not to transition into fielded equipment due a lack of procurement funding. This has always been an issue for the military and is likely to become more so in an era (for the West at least) of austerity and defence budget cuts. Even where defence spending is growing as it is in the Asia Pacific, it will likely remain the case that the number of potential technological ideas will exceed opportunities to transition those into equipment programmes.

Rapid technological change also poses challenge for the procurement process. Technology cycles in the civilian economy are shortening (witness the rate of change in Integrated Circuits) but weapons systems take longer to develop. This makes it increasingly difficult to take advantage of commercial innovations. "New" weapons are introduced that include technologies that are already obsolete. This raises huge questions for the defence acquisition process. How to make the defence acquisition process more agile and responsive to emerging technologies? How to insert the new technology when it is "good enough"? Various responses have been adopted or proposed including open system architectures and "spiral

[20] Murray and Millett (1996) *op cit.*

[21] I want to acknowledge with thanks the thoughts of Andrew Burton on this point.

development" and yet the divergence of the technology life cycles between civilian and defence equipment remains a profound challenge for the military acquisition process.

Critically, the adoption of a new technology is dependent on the response of the military. In the civilian economy, competition stimulates innovation and determines which new technologies are adopted. In the military innovation system, which new technologies are adopted is determined by bureaucratic and political decisions. In peacetime, the military is characterised by conservatism towards innovation. Military innovation arises out of inter- and intra-service rivalries as well as interactions and negotiations between the military and civilian "champions" of innovation.[22]

Joy's Law, "Military" Technologies and Open Innovation

A further point needs to be appreciated if we are to understand the nature of emerging technologies. We no longer live in the 1960s where U.S.' defence R&D spending accounted for something like half of all defence *and* non-defence R&D spending in the world. At that time, U.S.' defence R&D and procurement was able to stimulate whole new technologies (like semiconductors). However, this state of affairs did not last. Defence R&D remains important for the development of certain defence-specific technologies and knowledge but, more broadly, the defence innovation system has grown isolated from civil technology developments as a consequence of economic and technological change.

Defence is playing a declining role as a sponsor of advanced technologies and will become a follower rather than a leader in many (most) areas of technology. "Emerging technologies" are more likely to emerge from non-defence than defence sources.[23] Consequently, most emerging technologies will arise from scientific, technological and innovative activity taking place in civilian sectors, small firms and universities *world-wide*. At the same time, discussion of "military" technologies will become increasingly redundant. There may be a very few technologies (e.g. those related to low observables) that have strictly military application. However, most technologies will arise out of the dynamics of global non-defence innovative activities: the technologies may have military relevance but they are unlikely to be "military" technologies *per se*. To emphasise a point made earlier in this paper, too often advanced technologies are discussed in the abstract but it is the combination of technologies into military systems and the development of doctrine, training and organisation to exploit them to best effect that is the key issue for military capability.

The changing dynamics of technology mean that Defence in the United States and Europe will have to accept Joy's Law. As Bill Joy, Co-Founder of Sun Microsystems, said: "No matter who you are, most of the smartest people work for someone else". For most countries, it is increasingly apparent that most smart people work somewhere else. Joy's Law represents a profound shock for the defence innovation systems of many countries, not least the United States (where, for a long time, many of the smartest people did work in U.S. defence). In the future, the defence innovation process will need to place more emphasis on the timely identification and effective exploitation of emerging technological knowledge wherever it resides. The future of defence technology policy is likely to be in building absorptive capacity and agility by developing effective search mechanisms to identify potentially important emerging technologies and their sources, building effective partnerships with (potentially) non-traditional suppliers of such technological capabilities, and finding means for the agile exploitation of those emerging technologies to military advantage.

Such an approach is already commonplace in many sectors of the civilian economy where companies increasingly practice what has become known as "open innovation".[24]

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[22] See Grissom, (2006) *op cit* for a review of the work of Posen; Rosen; Murray and Millet; Pierce and others.

[23] See Alic, J.A., Branscomb, L.M., Brooks, H., Carter, A.B. and Epstein, G.L. (1992) *Beyond Spin-Off: Military and Commercial Technologies in a Changing World*. Boston: Harvard Business School Press; Cowan, R. and Foray, D. (1995) Quandries in the economics of dual technologies and spillovers from military to civilian research and development. *Research Policy* 24 851–868; Molas-Gallart, J. (1997) Which way to go? Defence technology and the diversity of 'dual-use' technology transfer. *Research Policy* 26 367–385.

[24] Huston, L. and Sakkab, N. (2006) "Connect and Develop: Inside Procter & Gamble's New Model for Innovation", *Harvard Business Review* (March): 58-66.

Open innovation is the idea that organisations should seek, engage and exploit knowledge wherever it resides.[25] Open innovation is already common practice in many other sectors. Under open innovation the ability to engage effectively with external suppliers of technological knowledge becomes a key competence. The challenge for Defence – both government and industry – is to develop those skills and competencies necessary to engage with non-traditional suppliers who will most likely be from outside the traditional boundaries of the defence innovation system. The closed innovation has been struggling to accommodate dual-use technological change and budget constraints for years. Recent developments, however, mean that the closed innovation model is finally broken. Importantly, technologies critical to defence are increasingly civilian in origin and global in nature and this explains why governments across the world are seeking to access non-traditional sources of technology for defence.

Many – most – of the emerging technologies identified as potentially important to defence are not of defence origin but are emerging from commercial R&D activity taking place in civilian sectors, SMEs and start-ups and in universities throughout the world. The defence innovation process will need to place more emphasis on the efficient exploitation of technological knowledge wherever it resides and take advantage of the significantly greater investments made in markets outside of its control or influence. The emphasis will have to be on exploiting technologies rather than large investment in new cutting edge technologies in all but a few defence critical areas.

Accordingly, one of the key competencies that Defence will need to develop in an era of open innovation is that of *absorptive capacity*. The idea of absorptive capacity is clearly understood by many non-defence technology companies, namely that the ability of a firm to recognise the value of new, external information, assimilate it, and apply it to commercial ends is critical to its innovative capabilities.[26] Absorptive capacity in the Defence context will mean the ability to (i) develop effective search mechanisms to identify potentially important external technologies outside Defence and their sources, (ii) build effective partnerships with (potentially) non-traditional suppliers of such technological capabilities, and (iii) find means to exploit those capabilities to military advantage.

Policy Implications

A number of policy implications arise from this discussion.

First, emerging technologies can have significant implications for military capability but the path from technological emergence to military capability is a long and uncertain one. Many immature technologies fail to live up to the promises of their advocates. Hype is common; failure even more so. The nature of the acquisition process not least its agility and responsiveness to new technologies is critically important. Equally so is the recognition that the combination of mature technologies in use can also have profound implications for military capability. The shock of the old can be just as great as the shock of the new.

This raises a second point, namely whether we should use an absolute or relative measure in judging whether a technology is "emerging". What is a mature technology in one country may be an "emerging" technology for another country or region (in our case the Asia Pacific). This raises important issues about the diffusion of military technologies and innovation that were the subject of an excellent collection edited by Emily Goldman and Leslie Eliason.[27] Arms transfers and cooperation play an important role in this process and will grow as European, U.S. and other governments and companies seek to gain a share of growing defence procurement budgets in the Asia Pacific. Equally, the relative capabilities of national innovation systems are likely to be an important consideration. Most of the true emerging technologies identified in futures studies are emerging globally, and defence is likely to play only a minor role as sponsor and user. The strength of national innovation systems (rather than just defence innovation systems) will be important.

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[25] Chesbrough, H. (2003) *Open Innovation,* Harvard Business School Press: Boston.

[26] Cohen, W.M. and Levinthal, D.A. (1990) "Absorptive Capacity: A New Perspective on Learning and Innovation", *Administrative Science Quarterly* , 35 (1): 128-152.

[27] Emily O. Goldman and Leslie C. Eliason (eds) (2003) *The Diffusion of Military Technology and Ideas*.

Cold War thinking about the dominant global position of the United States through its home-grown defence technologies is declining in relevance by the day.[28] The further growth of the already considerable scientific and technological capabilities of the Asia Pacific region is likely to have significant implications in the field of emerging technologies.

The gulf between the most advanced technologies being applied for military use by the United States and those of much of the Asia Pacific region is considerable. The difficulties (and cost) of trying to close the gap are enormous and beyond the scope (and ambition) of regional actors. Since it is impossible to forecast the eventual outcomes of emerging technologies, and since few (if any) countries have the resources to pursue all emerging technologies, this raises important strategic questions: should a country seek to pick a winner? Should it lag behind and hope that an ally invests in the technology, and is subsequently willing to transfer that technology, or does a country seek to follow all of them but develop processes that allow it to know when to stop when initial expectations prove unfounded? A small country may choose to lag behind and simply invest in adsorptive capacity (to access commercial technologies) and/or a limited range of distinctive capabilities that allows it to enter into cooperative arrangements with other countries. This suggests that investments should be in scanning the environment and in absorptive capacity rather than seeking to sponsor new technology development which speaks to an "open innovation strategy". This suggests that the use of more mature technologies in new ways is a more likely direction of development for Asia Pacific militaries. We are already seeing such developments, not least in the development of military capabilities in cyberspace.

Conclusion

The aim of this paper has been to examine the nature of emerging technologies and their potential impact upon military capability. This paper has defined "emerging technologies" as new technologies that are at an early stage in their development or relatively mature technologies combined in new ways. This paper examines the nature of emerging technologies, their implications for military capability and the challenges that they pose to the acquisition system. The paper has emphasised that their emergent nature means that they are characterised by considerable uncertainty: at its core, the paper stresses that it is a potentially long and uncertain journey from the emergence of a new technology to its use in a fielded weapons system.

Such issues are important because new technologies have the potential to change the environment in which militaries operate and a radical new technology can change the balance of power or create new forms of insecurity. New technologies can change military doctrine and the way that war fighting is conducted. New technologies can make existing defence systems obsolete or provide new and more effective military capability. By and large, attention has tended to focus on new-to-the-world technologies yet – as this paper has emphasised - novel combinations of existing and mature technologies can also have profound military implications.

How emerging technologies of military importance are identified and integrated into weapons systems through the acquisition process is a critical issue. The rate of technological change – driven by technological and economic factors mainly from the civil sector – places a premium on agility and responsiveness of the defence acquisition system. At the same time, it suggests the need for a profound shift from a closed towards an open model of defence innovation.

Acknowledgements

I wish to thank Hugh Cameron (University of Manchester) and Andrew Burton (Imperial College London) for their helpful discussions on this topic. I also wish to acknowledge the very useful comments and discussion at the MacArthur Foundation funded workshop on Emerging military technologies and their impact on the Asia Pacific at the S. Rajaratnam School of International Studies, Nanyang Technological University, Singapore, January 2013.

[28] This is recognised if not always by some within the defence-industrial-scientific complex. For example, see the National Academies (2009) report, *Beyond "Fortress America": National Security Controls on Science and Technology in a Globalized World.*

Author's Biography

Dr Andrew D. James is a Senior Lecturer at Manchester Business School and Senior Research Fellow at the Manchester Institute of Innovation Research. Andrew is the author or co-author of more than fifty academic journal publications, book chapters and public domain reports and his research focuses on the application of core frameworks from the academic literature on technology strategy and innovation management to the particular challenges and particularities of the security and defence sectors.

About the Project on Strategic Stability in the 21st Century Asia

Since June 2012, this project by the Institute of Defence and Strategic Studies (IDSS is a constituent unit of RSIS) has been engaged in identifying and analysing the key sources of strategic stability and instability in contemporary Asia. We sought to augment the prevailing understanding of how forces that stabilise Asia can be strengthened, and how forces that destabilise Asia (or have the potential for doing so) can be managed, and their adverse effects mitigated or contained.

The project addresses three key research concerns: First, examine major power relations in Asia. Second, analyse interstate dynamics within the maritime domain. And finally evaluate the impact of new and emerging military technologies in Asia. To that end, we organised three workshops during January-February 2013. We also commissioned a number of policy briefs, research papers, monographs, and edited volumes on critical security issues that have the potential to affect the security order in Asia over this decade.

The project is funded through a grant from the Chicago-based John D. and Catherine T. MacArthur Foundation.

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S. RAJARATNAM SCHOOL OF INTERNATIONAL STUDIES

A Graduate School of Nanyang Technological University

S. Rajaratnam School of International Studies, Nanyang Technological University
Block S4, Level B4, Nanyang Avenue, Singapore 639798
TEL 65 6790 6982 | FAX 65 6793 2991 | EMAIL wwwrsis@ntu.edu.sg | WEBSITE www.rsis.edu.sg