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4th Generation R&D: A Strategic Enabler for Transformation

La R&D de 4ième génération : un habilitant stratégique pour la transformation

By/par

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Abstract

This paper looks first at the state and pace of technology development, and its increasing importance in all aspects of our society, including the military. It is observed that technology has become a critical issue to the Canadian Forces (CF) due to its frenetic development pace, to the costs associated to the development and the insertion of these technologies into military capabilities, and to the need for interoperability with allied nations. Transformation as a concept is reviewed and put in context with what is being done in both the United States and Australia. Experimentation is then discussed as a key enabler for transformation. It is argued that a research and development management approach based on pro-activity, experimentation and modeling in close collaboration with the CF to help them determine their requirements for emerging technologies could represent a strategic enabler for their transformation in a foreseeable future. This methodology, based on the 4th Generation R&D concept presented by Miller and Morris[1], is then positioned with relation to Defence Research and Development Canada (DRDC) and its various research programs.

Résumé

Cet essai débute sur un bref survol de l'état d'avancement et la progression de la technologie et de son importance de plus en plus prédominante dans tous les aspects de notre société, incluant les militaires. On observe que la technologie est devenue un sujet critique pour les Forces armées canadiennes (FC) en raison de son rythme effréné d'avancement, des coûts qui sont associés à son développement et à son insertion en des capacités militaires, ainsi qu'à l'impératif d'*interopérabilité* avec les pays alliés. Le concept de transformation est passé en revue et mis en contexte avec ce qui se fait présentement aux États-Unis et en Australie. L'expérimentation est ensuite discutée comme un habilitant-clé de la transformation. On argumente qu'une approche de gestion de la recherche et développement axée sur la pro activité, l'expérimentation et la simulation de façon étroite avec les FC afin de les amener à définir leurs besoins face à des technologies émergentes pourrait représenter un habilitant stratégique pour la

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[1] Miller, William L., 1944. *4th generation R&D: managing knowledge, technology, and innovation / William L. Miller and Langdon Morris.* (New York: John Wiley, 1999).

transformation à laquelle les FC font et feront face dans le futur envisageable. Cette approche, basée sur le concept de la 4^{ième} génération de R&D présentée par Miller et Morris[2], est ensuite mise en perspective avec l'Agence R&D pour la Défense Canada (RDDC) et ses divers programmes de recherche.

[2] *Ibid.*

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Introduction

"*If you don't like change, you're going to like irrelevance a lot less*."

General Erik K. Shinseki
US Army's 34th Chief of Staff

This phrase vividly illustrates the impact of today's technology state – and pace - of development, and its dramatic consequences on any modern armed forces. This rapid (and ever-increasing) pace has profound consequences on the ability of the Canadian Forces (CF) to keep up with what technology can provide in terms of evolutionary and revolutionary capabilities, especially within tight budgeting constraints. It is realized that current processes and methodologies are becoming insufficient to enable insertion of pertinent technologies in the battlefield in an efficient, timely and cost-effective manner. Moreover, the selection of these pertinent technologies becomes a very difficult exercise, especially in the context of inserting potentially disruptive technologies[3] that will provide significant capability evolution/revolution for the CF.

This paper argues that technology is no longer the subject of a "revolution" in military affairs as it has become pervasive in both civilian and military sectors. New ways of identifying and exploiting novel and emerging technologies and the possibilities they can offer to the CF must be explored in a coordinated, efficient and cost-effective manner so as to enable a continuous and pro-active process instead of a reactive one. 4th generation Research & Development (R&D) is a process characterized by a pro-active management of R&D that aims at involving the potential users at the very first moment of the exploration of new technologies so to help them in defining their requirements for these technologies in existing or new capabilities. Arguably, the process could form the

[3] Several definitions are available for 'disruptive technology'. A generic one can be found on the SearchCIO WebPages as "(…) a new technology that unexpectedly displaces an established technology (…) Disruptive technology lacks refinement, often has performance problems because it is new, appeals to

basis for strategic technology acquisition and insertion, and lead to the insertion of disruptive or transformative capabilities. The process entails a spiral development approach that heavily involves continuous simulations and experimentations with the "customers" (or "users" in the military context) so that further iterations, if deemed appropriate, are refined towards the final demonstration and insertion of a transformational capability.

This paper explores only the technological aspects of transformation. As the Chief of Defence Staff (CDS) pertinently says in the introduction message of his annual report 2002-2003, "*While the pressure to transform is being driven largely by new technologies, transformation itself is not only about technology. It is about changing human, organizational and warfighting behaviour*."[4] Indeed, the rapidity of technological innovation causes almost inevitable lags in the development of strategic and tactical doctrines[5]. However, the aspects of transformation related to organizational, doctrinal, cultural and other non technology-related changes represent a separate and distinct area of study and as such, will not be addressed in this paper.

A Note on 4th Generation R&D VS 4th Generation Warfare

4th generation warfare is described in several papers by various authors. Some argue that it is an abstraction which is unrealistic and that 3rd generation warfare still predominates. Although it is generally not simplified to "High-Tech" warfare, technology has a predominant role to play in its current form and definition. 4th generation R&D and warfare are not directly related, but are certainly interconnected by their very nature. While the former deals with a new approach to manage the R&D and technology insertion processes in a more efficient and discriminate way, the latter reflects

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a limited audience, and my not yet have a proven practical application." Available from http://Searchcio.techtarget.com/sDefinition/0,,sid19_gci945822,00.html, Internet; accessed 4 April 2004.

[4] Department of National Defence. *A Time for Transformation – Annual Report of the Chief of Defence Staff 2003-2004* (Ottawa: Chief of the Defence Staff, June 2003), II.

the utilization of these novel technologies on the battlefield, combined with other factors such as politics, economics, and society. The notion of terrorism is also often associated with 4th generation warfare. It is sound to state that technology is an enabler to 4th generation warfare, as Lind et al propose in their paper.[6] They also point at the need for new R&D and procurement processes to transition pertinent technologies into military capabilities.[7] 4th generation warfare is characterized by small, agile forces focused on flexible missions, with decreased dependence on centralized logistics, and employing a growing use of technology. To avoid further confusion, no further attempts will be made in this paper to establish a relation between these two concepts.

About Technology

This section aims at illustrating the very rapidly evolving nature of technology and the increasing development pace. Are the processes and methodologies we are accustomed to still capable of following that pace? The answer, as will be concluded, is negative, and will point at the necessity to find new ways of addressing emerging and potentially disruptive technologies.

Technology development is now driven mainly by the civilian sector, and pure military technologies are now becoming the exception more than the rule. In other words, the majority of technological applications on the battlefield are derivatives or applications of civilian technologies. Past is the time when major inventions and technological innovations were produced by military-funded research, sometimes with dual-use in the civilian sector. As stated in *Future Forces*, published by the directorate of Land Strategic Concepts:

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[5] Garnett, John, *Contemporary Strategy I: Theories and Concepts (second edition)*, ed. John Baylis, Ken Booth, John Garnett and Phil Williams (New York/London: Holmes & Meier, 1987), 97.
[6] Lind, William S. et al, "The changing face of war: into the fourth generation", *Marine Corps Gazette* database online . (Quantico: Nov 2001) - cited 16 February 2004 . 85 (11): 65-68.
[7] *Ibid*, 67.

> *Shrinking defence budgets will not allow militaries of the future to be the dominant source of technological innovation they once were. (…) Since the consumer market is to a large extent financing new technological innovations, the military will need to leverage the commercial sector in order to militarize those advanced technologies that can best augment military capabilities.*[8]

Technology is now ubiquitous in our society. Anywhere we turn, we can see examples of technology that are part of our day-to-day lives. And the pace at which it is progressing is simply phenomenal. The exponential nature of technology evolution is well explained and illustrated in a paper by Ray Kurzweil, an American engineer that made significant contributions in the field of information technologies. Although perhaps over-optimistic and enthusiastic in his statements, he certainly presents very convincing evidence that *"(…) technological change is exponential, contrary to the common-sense "intuitive linear" view. So we won't experience 100 years of progress in the 21st century – it will be more like 20,000 years of progress (at today's rate)*."[9] The natural tendency to view the progression rate as linear is sometimes explained by the small sampling one's life represents on the curve, which can be approximated by a straight line instead of an exponential curve. He presents evidence that not only the progression rate of technological development is exponential, but also that the acceleration of this progression rate is exponential. The easiest (and probably best known) example of such an observation is the evolution of computing capacity. The initial "Moore's Law", enunciated in the mid 1970's, predicted that the number of transistors which could be packed on an integrated circuit doubled every 24 months. The combined effect of the increased number of transistor and the reduction of the distance between them provided an overall quadrupling of computational power. Reality now shows that the cycle has

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[8] Department of National Defence, *Future force: Concept fur future army capabilities* (Ottawa: Directorate of Land Strategic Concepts, 2003), 42-43.
[9] Kursweil, R., "The Law of Accelerating Returns", available from http://kursweilai.net/articles/art0134.html; Internet; accessed 4 March 2004.

decreased to 18 months in recent years, supporting Kurzweil's observations on the exponential growth of… the exponential growth!

Kurzweil goes even further in the definition of what he calls the *Law of Accelerating Returns* (which is also the title of his paper). Without going into details, it can be summarized with the following sentences extracted from his paper:

> *Technology goes beyond mere tool making; it is a process of creating ever more powerful technology using the tools from the previous round of innovation. (...) There is a record of each stage of technology, and each new stage of technology builds on the order of the previous stage.*[10]

In simple terms, technology is not invented every time from a clean slate, but rather relies on the previous level from which it is developed, hence multiplying the progression rate.

Although the previous examples dealt mainly with computer and information technologies, it is anticipated that major developments in several technological fields are going to have profound effects on our society in the coming 10 to 20 years. These are referred to as the NBIC technologies in *Future Force.*[11] NBIC refers to ***N****ano-science and nanotechnology,* ***B****iotechnology and biomedicine,* ***I****nformation technology, and* ***C****ognitive science*. It can be expected that advances in these specific fields will lead to disruptive technology insertion. Indeed, one of the examples provided (adaptive camouflage) is already being studied by the Defence R&D Canada (DRDC) Agency, and could lead to significant improvements to vehicle camouflage in a relatively short future. One can only begin to imagine what nano-science will be able to accomplish when the direct manipulation and laying-out of atoms becomes possible on a routine basis.

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Materials, structures and devices previously unimaginable will be developed, and should have a tremendous impact on existing technologies.

As a final, general comment on technology, what was seen as science fiction not so long ago could become reality in a not so distant future. This statement is well illustrated by a paper written by General (Retired) Paul Gorman entitled The Defence of Fombler's Ford.[12] Gorman describes through a series of dreams the components of futuristic military forces that will rely on various robotic, enhanced sensors, information and weapon systems to conduct warfare. What he describes are the components of the Future Combat System (FCS) that should be fielded by the end of this decade, demonstrating that reality can overcome imagination.

The Canadian Forces and Technology

These observations on technology lend themselves to the obvious conclusion that technology will only continue to grow in our lives. This is a reality, not a choice. Hence the question is not really if technology is an option for the CF, but rather how to make the best out of it in terms of military capabilities, within budgetary constraints that will always remain a reality to military forces planners.

It must be noted here that technology as such is not to be seen as a stand-alone answer to transformation. As noted by Maj. Kilenda in his paper, "*The future will belong not necessarily to the most technologically advanced combatant but the one that understands the nature of war and can most effectively cope with and exploit it.*"[13] Hence technology is not a panacea, but rather an enabler for the necessary transformation of the CF towards a more effective military force.

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[12] Gorman, Paul, "The Defence of Fombler's Ford", available from http://cpof.ida.org/FomblersFord.pdf, accessed on 4 April 2004

[13] Kolenda, Christopher D., "Transforming how we fight – A conceptual approach", *Naval War College Review*, Spring 2003, Vol LVI, No. 2, 101

One could argue that for the types of missions in which the CF are involved, technology might not play such an important role. For example, in recent years the CF have been involved mainly in peacekeeping and peace enforcing missions that are often seen as having more to do with humanitarian aid than anything else (a recent exception is Afghanistan). In such situations, it can be questionable whether sophisticated technology is required, as it would be of little help to prevent suicide attacks on our soldiers such as that experienced in the tragic events earlier this year.[14] Although there is some truth to such an evaluation, it should not lead to the conclusion that technology is irrelevant to the CF.

The type of engagement into which the CF are likely to get involved in the future will certainly be an important factor to consider in the selection of the required technologies and capabilities. Van Creveld states that "*The shorter the war, the greater the importance of weapons and weapons systems. The longer it is, the greater the role of military activities other than fighting pure and simple, and the greater the role of technologies that impinge on these activities or govern them.*"[15] Although it is difficult to accurately predict the type of missions that will be devoted to the CF in the future, it will nevertheless be necessary to determine what the Canadian government expectations will be for its military force, and make careful decisions on the capabilities that should be maintained/acquired with relation to these. The methodology proposed later in this paper to improve the pertinence of the investment in selective technologies that will help establish/maintain these capabilities in the future should contribute to the overall process.

This is especially true as technology has a cost, and generally a high one. As Boyer mentions in his article, "*The new high-tech warfare is costly, and one way to pay for it is to reduce low-tech inventory – the Army soldier, and the structures and big war*

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[14] Reference is made to the tragic death of Corporal Jamie Brendan Murphy who died after the attack of a suicide bomber in Afghanistan on 27 January 2004.
[15] Van Creveld, Martin. "The Logic of Technology and of War." *Technology and War: From 2000 B.C. to the Present* (New York, NY: The Free Press, 1989), 312.

machines that support him"[16]. Although this quote must be taken in an American context, and addresses mainly capabilities in the high end of the engagement spectrum, it nevertheless states a reality that also applies to the CF. Hence there is a necessity to make sure that the appropriate mechanisms and procedures are in place to ensure good choices of technologies and capabilities for CF roles and missions. And the idea at the heart of this essay is to identify key parameters that should form the basic principles to be implemented in the near future if we (the DRDC Agency) fulfil our core mission which consists of ensuring that the CF remain technologically prepared and relevant.[17]

Some might ask why the Department needs to invest in R&D, instead of buying technology wherever it is available. The answer to this question is multi-faceted. First, in order to be a "smart buyer", the Department needs to maintain a technological expertise that can provide sound advices whenever they are required. This can only be achieved through a sustained in-house effort in R&D by dedicated scientists on a permanent and continuous basis. Second, Canada is a world leader in several technological areas. Communications, hyper spectral imagery, electro-optical warfare are just a few examples. These technologies have enormous potential on the battlefield that justifies the investments made. And third, technologies that are tailored to military needs often become strategically sensitive, which therefore limits their access to foreign countries. Often times, the only way to access these technologies is via collaboration agreements that require Canada to invest in either complementary or niche technologies in order to have something to offer in exchange of the access provided.

The Need for Interoperability (or the threat of irrelevance)

The main and foremost reason that makes technology (and its evolution/revolution) impossible to avoid in the CF is the need for interoperability with

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[16] Boyer, Peter J. "A Different War: Is the Army Becoming Irrelevant?" *The New Yorker,* July 1, 2002, 63.
[17] Department of National Defence, *Looking Forward Staying Ahead … Enabling Transformation 2003* (Ottawa: Defence Research and Development Canada, 2003), 6.

its allies, and more specifically with the US. The most obvious (and arguably the most predominant) area of interoperability concerns information technologies. This aspect of technology has been discussed extensively in several papers speaking of the Revolution in Military Affairs (RMA). Middlemiss and Stairs present a thorough review of the issues related to interoperability. They strongly argue in favour of a fully-fledged interoperability arrangement with the US that would provide the CF with the capacity to operate both independently and in full cooperation with their American counterparts.[18]

Sloane[19] presents a good overview of the RMA in the Canadian context, and she emphasizes the need to remain technologically up to date within the CF if they want to remain relevant for operations with allies. This observation is especially accurate as most (if not all) operations in which the CF are (and will likely be) involved are in coalitions with allied nations. As Military Assessment 2000 clearly enunciates:

> *During combined operations, access to, and integration within, the coalition information grid is critical. Recognising this imperative, the CF should monitor and, where useful, collaborate in allied analysis and experimentation that address combined and inter-agency issues. Given US predominance (from both the military and technical perspectives), the CF must ensure that it possesses the ability to be interoperable with US information systems."*[20]

The above citation refers specifically to interoperability with coalition forces and the US information technology (IT). IT interoperability might arguably be the most crucial technological area for the CF. It is nevertheless not the only aspect that has to be

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[18] Middlemiss, Danford W. and Stairs, Denis, "The Canadian Forces and the Doctrine of Interoperability: The Issues". *Policy Matters*, Vol 3, No 7 (Halifax: The centre for Foreign Policy Studies, June 2002), 30
[19] Sloan, Elinor C. Chapter 8, "Canada and the RMA." *The Revolution in Military Affairs — Implications for Canada and NATO.* Kingston, ON: McGill-Queen's University Press, 2002, 141–142.
[20] Department of National Defence, *Military Assessment 2000*; available from http://www.vcds.forces.gc.ca/dgsp/00native/rep-pub/dda/milassess/2000/MilAssess_e.pdf; Internet; accessed 30 March 2004, 52.

addressed in terms of technological relevancy. Indeed, as technology continues to evolve, it will most certainly be necessary to ensure that most aspects of the CF capabilities offer the possibility to interoperate with allies, hence the necessity to follow the developments as they evolve. Failing to modernize and transform would, without any doubt, lead to an inability to conduct coalition operations, and to remain "…*able to fight 'alongside the best, against the best'*."[21]

This point is further emphasized in the CF Strategic Operating Concept, currently under definition. Although the document is still being drafted, it contains several statements on the need for the CF ability to conduct multinational operations as a key aspect of most, if not all, international and continental operations. Needless to say, the ability to integrate with the US Armed Forces will remain of critical importance.[22] The relationship with the US will remain one of the main drivers for Canada to remain interoperable with its giant ally. Without adequate technological development, interoperability becomes an illusion.

Finally, the danger of irrelevance due to obsolescence is further emphasized in Future Force – Concepts for Future Army Capabilities:

> *Without greater efforts to tap into new defence related innovations, as well as an increased commitment to match procedures governing the acquisition and procurement of essential equipment to evolving technological realities, the Canadian Forces and the nation's value as an ally, may become increasingly anachronistic and irrelevant as time goes on.*[23]

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[21] Department of National Defence, *1994 Defence White Paper*, (Ottawa: Canda Communications Group, 1994), 14.
[22] Department of National Defence, *Canadian Forces Strategic Operating Concept*, DRAFT 3.4, 12 March 2004
[23] Department of National Defence, *Future force: Concept fur future army capabilities* (Ottawa: Directorate of Land Strategic Concepts, 2003), 5.

This is indeed why the Department (and consequently the CF) must adopt processes that will allow for the careful and discriminate selection of the technologies essential to the establishment and sustainment of their selected capabilities.

The Evolution Process: Transformation

The CF, recognizing the importance of evolving their capabilities with the introduction of new technologies and the accompanying doctrines on the battlefield, adopted in recent years a process to effect this evolution. This process has been designed as *transformation*. The US Office of the Secretary of Defense provides a generic definition of transformation: "*(…) changes in the concepts, organization, process, technology application and equipment through which significant gains in operational effectiveness, operating efficiencies and/or cost reductions are achieved*."[24]

It is not easy to find a universally adopted definition for the term. The Chief of Defence Staff (CDS) puts transformation as the central element of the CF agenda in his annual report 2002-2003[25]. Although no explicit definition is provided, the various elements that must contribute to transformation (i.e. organizational, doctrinal, cultural, just to name a few) are described. For the purpose of this paper, the following definition will be used. It is promulgated by the Director General Strategic Planning, and seems to be the most widely used in the Canadian context:

> *Transformation is a departmental process of strategic re-orientation in response to anticipated or tangible change to the security environment,*

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[24] United States, Office of the Secretary of Defense, *Transformation Study Report: Transforming Military Operational Capabilities* (Washington, DC: Government Printing Office, April 27, 2001), chart 5.
[25] Department of National Defence. *A Time for Transformation – Annual Report of the Chief of Defence Staff 2003-2004* (Ottawa: Chief of the Defence Staff, June 2003).

designed to shape a nation's armed forces to ensure their continued effectiveness and relevance.[26]

Technology (in the spirit of modernization) is certainly recognized as being at the "heart" of transformation[27]. The transformation process will not alleviate the requirement for the establishment of priorities. On the contrary, as stated in Military Assessment 2000:

Resource constraints will not allow the CF to initiate a single, comprehensive modernization of its military forces. Regardless, a clear understanding of emerging technology, coupled with an appreciation for the changing nature of conflict will allow "focused revolutions" within specific capabilities. This concept suggests that new technologies may offer revolutionary improvements to one or two capabilities rather than the complete transformation of a military force – a transformation that is currently beyond the resources of the CF.[28]

This presents a further argument for the establishment of new processes that will facilitate/entte/en *iterative process of improvement, refinement and adaptation; therefore, transformation is not linear*"[29]

Indeed, as transformation is intimately related to technology and its rapid evolution, transformation simply cannot be linear, and must provide a process of rapidly inserting pertinent technologies after careful selection and experimentation with them to ensure their usefulness in capabilities for the battlefield. To the contrary of what several official documents tend to imply, transformation is more than a step towards tomorrow's and future forces: it is indeed a methodology that should have a permanent nature. This idea is well expressed by Herbert Brown: "*The most important concept to grasp is that transformation is a journey, not a destination*"[30]

As this paper aims at addressing the technology aspect of transformation, it appears now quite clearly that there is an opportunity to introduce new science and technology (and more specifically research and development) management ideas and principles that will facilitate and enable the permanent nature of the required transformation. However before going to the concept of 4th generation R&D, it is useful to observe on what is being done in terms of transformation by our neighbour, the USA, as well as by a country that is more comparable to Canada in terms of its size, military force, and comparable power, i.e. Australia.

Transformation in the US

It would be hazardous to make direct comparisons between CF transformation and that of the US Forces. Indeed, in the US, transformation is a huge undertaking to say the least. The objectives, philosophy, and moneys invested are of a totally different

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[29] Department of National Defence, *Looking Forward Staying Ahead ...Enabling Transformation* (Ottawa: Defence Research and Development Canada, December 2003), 10

[30] Browne, Herbert A. "Transformation: A journey, not a destination" *Signal*, May 1, 2003, available from http://www.proquest.com/; Internet; accessed March 12, 2004, 14.

magnitude. Suffice to say that the US National Security Strategy[31] relies heavily on preemption and deterrence to understand the basic difference in defence philosophy. "*The new transformational capabilities that the military is pursuing are tailor-made for rapid and decisive preemption*"[32].

The definition provided in the same reference is also quite enlightening: "*(...) transformation is a process designed to change fundamentally the way we fight by adapting new technologies to warfare, developing advanced operational concepts to best use those technologies, and reorganizing military structures to execute those concepts*".

It is interesting to observe that although transformation was in principle initiated after the end of the Cold War, it really took its full momentum only a little over 10 years ago, shortly after Operation *Desert Storm*. Serious deficiencies were observed with relation to the expeditionary role demanded of the US Forces (rapid effect and deployability, agility, etc.). Since then, transformation has become an integral part of the US Forces strategic planning and development. Today, any program that is not considered "transformational" is likely to encounter great funding difficulties, if not simply to be terminated. This is indeed indicative of the importance given to transformation. The US process even involves a transformation *czar*, a transformation command, and a transformation budget.

One of the most comprehensive publications on the US transformation is a book edited by Hans Binnendijk, a Professor of National Security Policy at the National Defense University, entitled "Transforming America's Military"[33]. The publication addresses various aspects of transformation, going from the foundations of

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[31] United States, The White House, "The National Security Strategy of the United States of America", (September 2002), available from http://www.whitehouse.gov/nsc/nss.pdf; Internet; accessed 13 March 2004.

[32] Binnendijk, Hans, "Observations on military transformation", *Defense Daily*, Vol. 216, Issue 56, (Potomac, Dec 2002): 1.

[33] Binnendijk, Hans et al, *Transforming America's Military* (Washington, D.C.: National Defense University Press, 2002).

transformation, through the transformation of the services, the coordination of transformed military operations, and finishing with observations on broader aspects of transformation. Technology is acknowledged to be the basis of military transformation and the great enabler for it, and a large portion of the book looks at the harnessing of new technologies and the maintenance of a technological lead.

> *The process of transformation, consequently, requires developing a vision of how new technologies might benefit the military, funding the research and development of new technologies into weapons, maintaining an industry that can produce equipment embodying the new technologies, developing service doctrine to use those technologies effectively, and training troops to use the new capabilities.*[34]

Although this statement emphasizes the importance of maintaining the technological lead, the document does not specifically call for new ways of conducting and managing R&D. This can be partly explained by the huge investment that the US Department of Defense (DoD) makes in R&D, diminishing the impact of sometimes not developing only those technologies that are really pertinent to the desired capabilities. For example, the Defense Advanced Research Projects Agency (DARPA) is one of the lead players in the exploration of emerging technologies and their potential application on the battlefield. Just for Fiscal Year 2004, their total budget was $3B US[35]. This budget is only a fraction of the US DoD budget on R&D ($48B US FY02, estimated at $62B US in FY04[36]). Their basic philosophy is to fund several companies at the same time to see if there is more than one approach to a given technology. This is an approach that countries such as Canada cannot afford.

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[34] *Ibid*, xx.
[35] United States, Defence Advanced Research Project Agency, *Biennial Budget Estimates FY 04-05*, available from http://www.darpa.mil/body/pdf/FY04_FY05BiennialBudgetEstimatesFeb03.pdf; Internet; accessed 13 March 2004.
[36] United States, The White House, available from http://www.whitehouse.gov/omb/budget/fy2004/defense.html; Internet; accessed 14 March 2004.

It is also interesting to note that the gap between US and the rest of the world, in terms of military capabilities, is acknowledged and recognized as potentially having a negative impact on their allies. "*Further widening of this capabilities gap could undermine America's interest in NATO and reduce its willingness to listen to European concerns*"[37]. The recognition of this reality and of its implications in terms of the ability to operate in coalition could help enable the collaboration that is essential between Canada and the US to maintain the required level of interoperability. This reality is shared by several nations, as exemplified by a recent paper by William Moore providing a British view on this topic.[38] Binnendijk et al also address the existence of this gap, and acknowledge that the US will seek coalition partners in most future international initiatives. Their assessment is that the gap is not insurmountable, and that a concerted program of action is required to close it without imposing too much of a financial burden on allied countries[39].

On the other hand, despite the seemingly endless budgets devoted to it, transformation is not as "rosy" as it might appear in the US. Notwithstanding the gigantic efforts and investments devoted to transformation, even our neighbour has budgetary contingencies that prevent the progress oftransformation as rapidly as it should. Some observe that current equipment acquisition programs have not completely taken the turn towards transformed forces, and that legacy systems are still kept in the capabilities that do not meet the requirements of transformation. Sloan argues that "*(...) current equipment trends indicate that America's military is not so much transforming its forces as pursuing a more technologically advanced means of 'fighting the last war'.*"[40],

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[37] United States, The White House, "The National Security Strategy of the United States of America", (September 2002), available from http://www.whitehouse.gov/nsc/nss.pdf; Internet; accessed 13 March 2004.
[38] Moore, William H., "U.S. Army transformation: The U.K. view", *Military Review*, Volume 82, Issue 3, May/Jun 2002, 68-69.
[39] Binnendijk, Hans et al, *Transforming America's Military* (Washington, D.C.: National Defense University Press, 2002), xxvi.
[40] Sloan, Elinor, "Terrorism and the Transformation of US Military Forces", *Canadian Military Journal*, Vol 3, no 2, available from http://www.journal.forces.gc.ca/engraph/vol3/no2/pdf/19-24_e.pdf; Internet; accessed . 29 January 2004

mainly due to bureaucratic, political and financial restrictions. She, however, sees an opportunity with the war on terrorism to put the process back on track as most of the attributes that transformation will bring to the US Forces are indeed pertinent for such a war (i.e. smaller, more rapidly mobile, deployable and lethal ground forces, advanced C4ISR, etc.). This offers an argument for a shift in paradigms that is not easily achieved, and that could certainly be enabled by a new approach in R&D management that should inevitably involve experimentation and spiral development. This would help the CF "see by themselves" the benefit of the possible shifts in technology to be achieved via a well-coordinated transformation.

Australia and transformation

Transformation does not seem to be a term that is widely used in the Australian defence jargon. Indeed, the White Paper on Defence, produced in 2000, does not even allude a single time to it. It is clear however that modernization and science and technology are at the heart of their military strategy. The emphasis that is put on their R&D organization, the Defence Science & Technology Organization (DSTO) in the White Paper itself (a full chapter on S&T[41]) is revealing of the importance they put on technology, as well as the funding that is devoted to DSTO (2% of the total defence budget). When speaking with the Australian planners responsible for Technology, it is clear that even though the term is not used as such, they see that the principle of transforming their military forces as really central to any defence future for their country[42]. What is less clear is the difference made in Australia between *modernization* and transformation.

It would seem that although many think that the Australian Defence Force (ADF) needs to transform, there does not seem to be a feeling of urgent transformation for the

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[41] Australia, Department of Defence. *Defence 2000 – Our Future Defence Force* (Canberra: Commonwealth of Australia, October 2000), Chapter Ten – Science and Technology, 107-113

[42] This point was confirmed during a private conversation on 23 February 2004 with Mr. Brendan Sargeant, the Counsellor Defence Policy at the Australian Embassy in Washington.

ADF capabilities as much as for its structure, mission and doctrine. All these aspects are quite inseparable, but the technological aspect of transformation does not seem to be the main driver for their transformation. Dupont, in a recent paper in the Australian Journal of International Affairs, strongly expresses his opinion that the ADF is focused on past models of wars and missions, and emphasizes the urgent need for a transformation towards more modern models. He even uses Canada as an example of modern planning for its armed forces that aims at globally deployable combat capable forces[43]. He presents a fairly severe judgement on the Australian White Paper of 2000, and urges the main actors for a reorientation of the role of the ADF. Although he makes allusion to the need for modern technology, mainly as a requirement for coalition interoperability (primarily with the US)[44], he definitely puts technology at a lower priority than the restructuring of the forces.[45]

At a recent TTCP JSA TP-1[46] meeting, the Australian representative tabled a position paper that does indeed speak of transformation specifically for the Australian Army (i.e. Land Force). There seems to be some scepticism about all the attention put on transformation in the US. However, most of what is discussed in the position paper uses the same language and focuses on the same aspects that are generally referred to in the transformation vocabulary. Their emphasis though is put again on modernization rather than transformation. This indicates that their approach is more conservative than what the pace of technology development now calls for. There are, however, several indications that their modernization process must be accomplished through the use of experimentation and closer collaboration between the R&D world, the private sector producing the equipment, and the users. This could be interpreted as a logical (and

[43] Dupont, Alan, "Transformation or Stagnation? Rethinking Australia's Defence", *Australian Journal of International Affairs*, Vol. 57, No. 1, 2003, 68
[44] *Ibid*, 69
[45] *Ibid*, 70-71
[46] TTCP stands for "The Technical Cooperation Program", an agreement between UK, USA, Canada, Australia and New Zealand to collaborate on Defence R&D. JSA is the Joint Systems Analysis Group, and TP-1 stands for Technical Panel 1

perhaps unplanned) evolution of their current processes towards a more proactive methodology in the same vein as that proposed later in this paper.

The way ahead: an integrated process to select/develop/insert technologies

The previous sections provided some rationale for the transformation process required in order to keep modern military forces relevant and able to fulfill their tasks and missions. The US Forces are already well embarked on a transformation process that goes much further and deeper into all aspects of their capabilities and structures. As the only superpower nation at this point in time, they just cannot afford to not be ready to cover the full spectrum of engagement, and they are transforming to maintain a technological lead that is consistent with this broad role. It is, however, recognized that this transformation must be effected efficiently, and better processes are required to achieve this efficiency. As Binnendijk et al state:

> *If these transformations are to succeed, the processes used to acquire the new tools of war, as well as the research and development (R&D) infrastructure upon which they depend, must be transformed to meet the emerging requirements* [of transformation]. *Links between the military, the scientific communities, and the industrial communities are more vital now than they have ever been.*[47]

The same publication also identifies the need for a better mechanism to identify technologies in the early stages, and integrate these into the experimentation processes for rapid technology insertion. This indeed not only pleads for a better technology watch, but chiefly for a better integration of the R&D and acquisition processes[48].

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[47] Binnendijk, Hans et al, *Transforming America's Military* (Washington, D.C.: National Defense University Press, 2002), 346
[48] *Ibid*, 367-368

An illustrative way to demonstrate what is required in terms of process to accelerate and improve technology insertion is shown at Figure 1, reproduced from "Transforming America's Military". Traditionally, most R&D organizations would operate along the « *emphasis on discovery and experimentation* » curve, while companies and the CF would generally have a tendency to operate on the « *emphasis on system engineering* » curve. The management process that is now required implies a closer collaboration between all these players, and a "flattening" of the curve along the dotted line traced on top of the graph. This would have a direct consequence on the ability to select pertinent technologies, and would significantly reduce the amount of time required to explore and further develop the technologies to ultimately field them in concrete capabilities. This is exactly what is urged in Military Assessment 2000: "*The CF must develop a single methodology linking requirements, research, acquisition through to experimentation and the fielding of new equipment. In particular, the CF must shorten the programme cycle, acquiring new technologies quickly but with planned product improvements*."[49]

[49] Department of National Defence, *Military Assessment 2000*; available from http://www.vcds.forces.gc.ca/dgsp/00native/rep-pub/dda/milassess/2000/MilAssess_e.pdf; Internet; accessed 30 March 2004, 54.

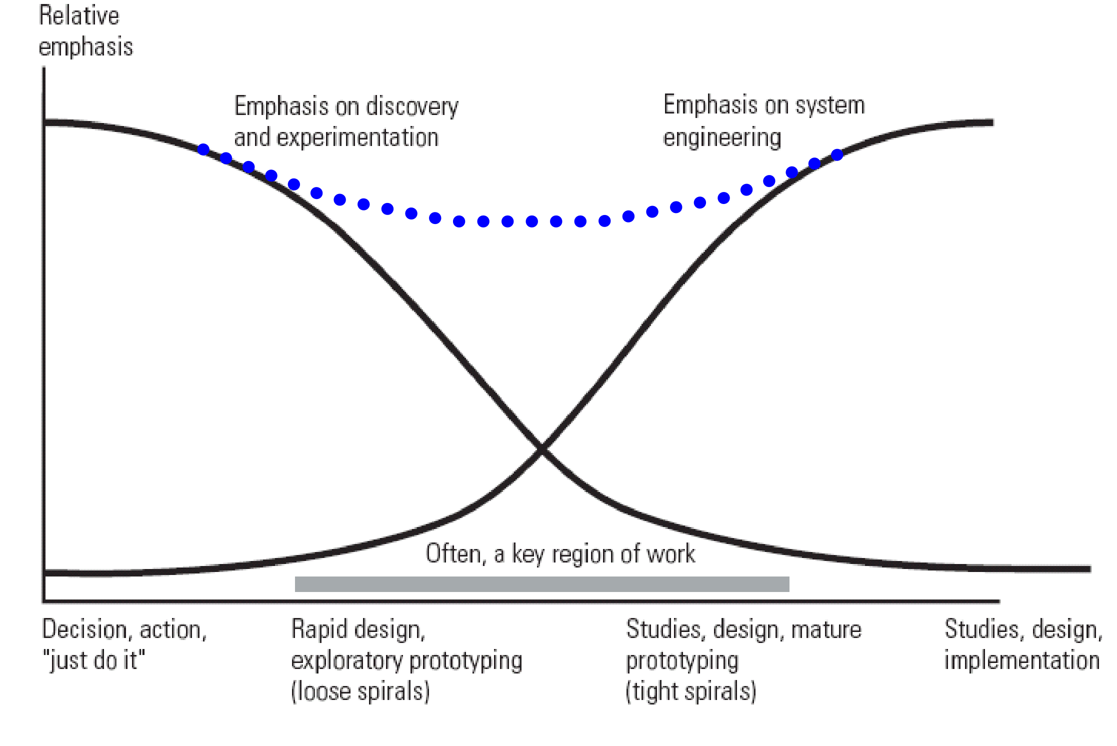

Figure 1: Approach required to facilitate rapid technology insertion into new capabilities

As will be seen later, 4th generation R&D presents opportunities for incorporating these required links in a well-structured process. At the heart of this process resides *experimentation*, which could be considered as the "glue" that connects research, development, requirements definitions, and rapid insertion of technologies on the battlefield.

Experimentation

In recent years, the US has established a Joint Experimentation Program with the main purpose of examining new technologies, concepts and force structure altogether rather than in isolation[50]. It is now well recognized by most nations that experimentation

[50] Binnendijk, Hans et al, *Transforming America's Military* (Washington, D.C.: National Defense University Press, 2002), 360-361.

is an essential tool for military force development. Experimentation is a "buzzword" almost as popular as transformation in the modern military jargon, especially when dealing with force development. It is important therefore to define what it means in the context of this paper, as well as that of the references used. In fact, it has a larger meaning than that generally understood in a scientific or R&D context, which would tend to refer to it as a set of tests following well-defined and rigid protocols, generally conducted in laboratories under carefully controlled conditions. The definition used here encompasses more than just the scientific aspect. Indeed, the idea is not to only test a technology, but rather the capability that the technology under investigation could eventually offer. Hence, it is essential that the end-user be involved in the experimentation so that he can explore it, and contribute to the determination of the potential requirements and benefits coming out of it. That being said, it should not be concluded that the conditions and metrics used should be less carefully controlled and measured than in a purely scientific experiment. Indeed, it is essential to ensure that rigour is applied in the planning and conduct of these experimentations.

So in the US, experimentation has become an integral part of most military acquisition processes. It forms a key element of what is now referred to as *spiral development*. In essence, spiral development takes advantage of the concurrent work of the researchers, engineers and users in a series of development followed by an experiment that explores the technology a little further, allowing for the identification of the deficiencies and advantages by both the researchers and the users, and hence accelerating the development of the final technology by rapidly closing in on the characteristics and requirements that will best suit the capability being sought. A good depiction of what is meant by spiral development in the US context is provided by the Pentagon acquisition chief Pete Aldridge in a memorandum discussed in the Defense Daily International:

> *An iterative process for developing a defined set of capabilities within one increment. This process provides the opportunity for interaction between*

the user, tester, and developer. In this process, the requirements are refined through experimentation and risk management, there is continuous feedback, and the user is provided the best possible capability within the increment. Each increment may include a number of spirals. Spiral development implements evolutionary acquisition.[51]

As will be seen later in this paper, spiral development as defined above is perfectly aligned with the philosophy of the 4th generation R&D.

Experimentation is well recognized as an essential process in the Canadian context for force development concepts. As stated in Military Assessment 2000, "*Experimentation is particularly useful at times of rapid and pervasive change. It allows for a thorough and broad consideration of issues prior to making expensive investments in equipment, potentially disruptive changes to organisations, or radical changes to doctrine*"[52]

The document further defines the necessity for Concept Development & Experimentation (CDE) and Modelling & Simulation (M&S) tools for force development. CDE is referred to as "*an iterative process of collecting, developing and exploring concepts to identify and recommend the best value-added solutions for changes to doctrine, organisation, training, material, leadership and people required to achieve significant advances in future joint operational capabilities*"[53]

In the past five years at least, numerous activities were held towards the development of CDE and M&S tools and capabilities in recognition of the essential nature of these tools for efficient force development. A cornerstone document is the

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[51] "Aldridge Memorandum Clarifies 'Spiral Development' Concept", *Defense Daily International,* Vol. 2, Iss. 25 (Potomac: April 26, 2002): 1.
[52] Department of National Defence, *Military Assessment 2000*; available from http://www.vcds.forces.gc.ca/dgsp/00native/rep-pub/dda/milassess/2000/MilAssess_e.pdf; Internet; accessed 30 March 2004, 48.
[53] *Ibid,* 48.

Concept Development and Experimentation and Modelling and Simulation document published by the Symposium Working Group in Nov 2000[54].

The recognition of the importance of experimentation in force development led to the creation of the Canadian Forces Experimentation Centre (CFEC) in 2001. CFEC was established to manage Joint experimentation projects, in support of both CDE and Material Acquisition and Support (MA&S) activities. Its mission is "*To lead the exploration and evaluation of emerging concepts to determine the capabilities required by the Canadian Forces*"[55]. Although a strong emphasis is put on modeling and simulation, CFEC also conducts experimentations in the field with actual hardware. Plan *Pegasus* is the first Canadian Forces Joint Concept Development and Experimentation Plan. It "*identifies and prioritizes key concepts and experimentation strategies that have the greatest potential to transform DND/CF and contribute to the realization of* Strategy 2020."[56] CFEC can explore technological concepts that are not necessarily readily available in order to identify the potential benefits. This can be accomplished in conjunction with the DRDC Technology Demonstration Program that will be discussed later.

4th Generation R&D

The preceding sections emphasized the unavoidable necessity for the CF to take advantage of technology for the sake of interoperability and transformation, and to ultimately remain pertinent and relevant in their mission. However, it was also seen that current processes and methodologies couldn't keep up with the accelerating development pace of technology in a cost-effective and timely manner. This emphasizes the

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[54] Department of National Defence, *Concept Development & Experimentation and Modelling & Simulation*, (Ottawa: Vice-Chief of the Defence Staff, 2001) available from http://www.vcds.forces.gc.ca/dgsp/pubs/rep-pub/dda/symp/cde/intro_e.asp; Internet; accessed 1 April 2004.
[55] Department of National Defence, *Canadian Forces Experimentation Centre*, available from http://dcds.mil.ca/dgjfd/cfec/default_e.asp; DWAN; Accessed 12 March 2004.
[56] Department of National Defence, Canadian Forces Experimentation Centre, *Canadian Forces Joint Concept Development and Experimentation Plan (CFJCD&E Plan), Plan Pegasus*, May 2002, i

requirement to find new processes not only for technology insertion, but also for technology *selection* and R&D management. This section presents a new concept of R&D management, based on a pro-active involvement of the users even before they are fully conscious of their needs and requirements. Miller and Morris explain the concept in their book, entitled "4^{th} Generation R&D", and most of the information and ideas presented in this section are obtained from this reference[57]. Although the book is really written for the private sector, and hence has a commercial connotation that does not necessarily ring with that of defence R&D, it presents very valuable principles that, for most part, could be adapted to the needs of the Department. These similarities will be evaluated and discussed at the end of this paper.

But before we explore the idea of the 4^{th} generation R&D, it is useful to describe what were the three preceding generations, as explained by Miller and Morris. The first generation R&D appeared in the late 19^{th} and 20^{th} century. It consisted in the first industrial research and development initiatives that were mainly driven and led by visionary inventors such as Thomas Edison, Henry Ford and Alexander Graham Bell. The authors attribute their success to "*…their mastery of research methodology, combined with their tremendous (and probably intuitive) grasp of the market development process*, which *enabled them to transform research innovations into commercial breakthroughs."*[58] It is important here to retain this idea of scientists' intuition to understand the nature of this 1^{st} generation R&D. The authors provide their definition of the process: "*Initially, research was managed by scientists who selected and conducted research projects that yielded many significant breakthroughs (…). In hindsight, the laboratories that were managed by scientists are now referred to as 1^{st} generation R&D labs*".[59] Another Canadian example of such scientists conducting 1^{st}

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[57] Miller, William L., 1944. *4th generation R&D: managing knowledge, technology, and innovation / William L. Miller and Langdon Morris.* (New York: John Wiley, 1999).
[58] Miller, William L., 1944. *4th generation R&D: managing knowledge, technology, and innovation / William L. Miller and Langdon Morris.* (New York: John Wiley, 1999), 12.
[59] Department of National Defence, Canadian Forces Experimentation Centre, *Canadian Forces Joint Concept Development and Experimentation Plan (CFJCD&E Plan), Plan Pegasus*, May 2002, i

generation R&D would be Joseph-Armand Bombardier, with his invention of the snowmobile in 1937 (first patent).[60] Bombardier conducted the research and development of his invention over a period of 10 years, and managed it entirely by himself. His first success led him to pursue the development of new products. It is really then that he managed a formal R&D process *à la* 1st generation R&D.

The main difference between the first and second generation of R&D is related to the realisation by corporate managers of the importance and potential benefits of R&D for their business. The 1st generation R&D evolved towards the 2nd generation during the first half of the century, and this evolution was accelerated before and during WWII to catch back on the technological developments of the Germans before and during the war. "*By then, corporate managers recognized that they must manage their labs with a greater focus on projects serving the needs of their business, and they applied and extended project management practices that were developed during the war. These are now referred to as 2nd generation R&D*".[61]

The 3rd generation R&D consists in the further formalization of the R&D processes, as well as the incorporation of *risk management* into the process. "*The practice of technology management in the context of financial risk, strategic planning, and technology road maps is called* 3rd generation R&D *(...).*[62] This type of management is a consequence of the constantly rising cost of R&D as well as the ever more rapid changes in technology that made the life cycle of new products shorter and shorter, making it a source of uncertainty in the investment strategy of any given company. At this point though, the R&D process remains in the "reception" mode with relation to the expression of the customers' needs and requirements. In this model, "*(...) only* [those] *customer needs that can be specifically articulated can be addressed. Such needs, also*

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[60]Musée Joseph-Armand Bombardier, available from http://www.fjab.qc.ca/en/content/jab/biographie1926_1938.htm; Internet; accessed 29 February 2004.
[61] Miller, William L., 1944. *4th generation R&D: managing knowledge, technology, and innovation / William L. Miller and Langdon Morris.* (New York: John Wiley, 1999), 14.
[62] *Ibid*, 15

referred to as "explicit" needs, constitute only the visible tip or the iceberg, the part of need that is above the surface of awareness."[63] The nature of this process makes the discovery and development of revolutionary (or disruptive) technologies the exception rather than the rule. Figure 2, reproduced from Miller & Morris[64], schematically illustrates a traditional process in the 3rd generation model.

This makes the case for the advancement of the process into a so-called 4th generation R&D. This process, as one could now guess, involves experimentation, simulation and *spiral development* right at the beginning (or rather on a continuous basis, as the process is open-ended by nature). The customer needs to get heavily involved in the process to make it a success. As expressed by the authors:

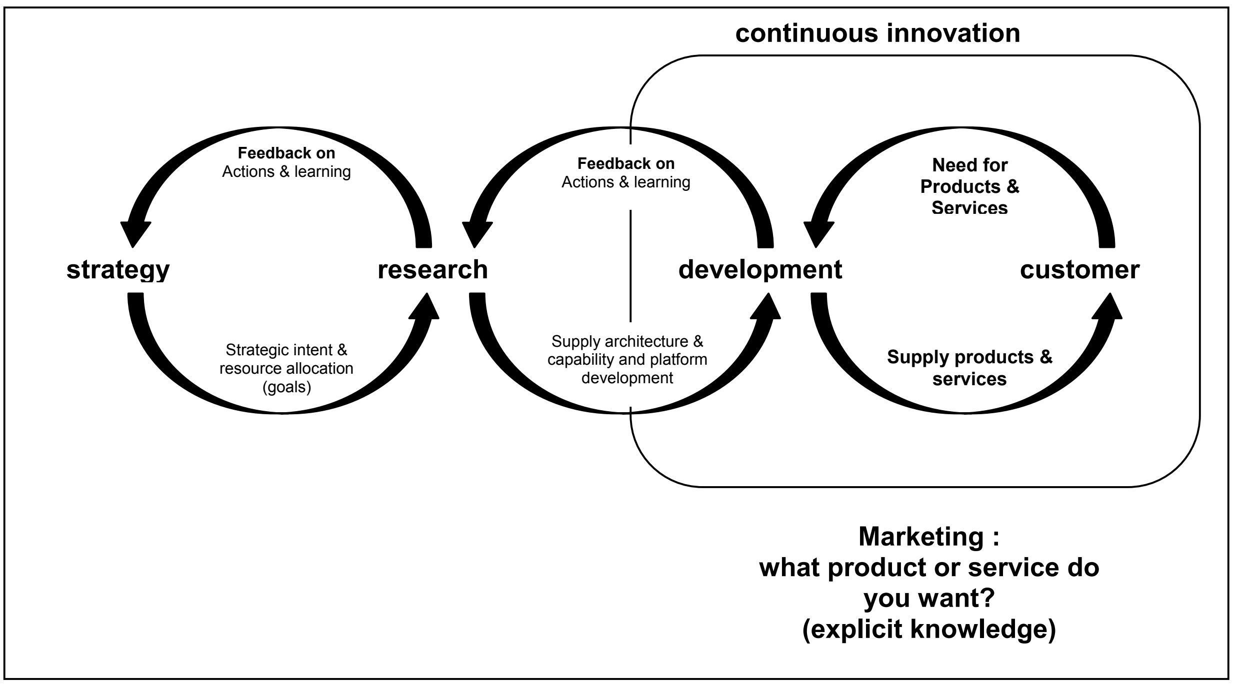

Figure 2: Traditional market research, reproduced from Miller & Morris

[63] *Ibid*, 16
[64] *Ibid*, 130

> *"The alternative (...) is the sharing of knowledge gained through experiments in which vendors, customers, and other stakeholders all participate. This takes place in the research process itself (...) Here, customer needs and technological capabilities coevolve linked to one another in the 4th generation R&D process of "mutually dependent" learning, in which technologically enabled capabilities and concepts are assessed and refined in the context of real need."*[65]

This type of R&D management stands much better chances to lead to *discontinuous*[66] innovation as a rule, rather than the exception. By its nature, it also significantly augments the chances that pertinent technologies will be identified early on in the process, and permits a better and more pertinent focus of the often-limited resources available to investigate any given technology. What the process really aims at is discontinuous innovation, rather than continuous innovation. As alluded to before, continuous innovation is the process that results from the definition of existing *explicit* needs of the customers. These explicit needs are based on the expression of explicit knowledge, and consequently generally lead to evolutionary technological products. Discontinuous innovation relies on *tacit* knowledge, which by nature cannot be explicitly expressed. It generally leads to revolutionary technologies and capabilities. Figure 3, reproduced from Miller and Morris[67], illustrates the new approach of the 4th generation model.

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[65] Musée Joseph-Armand Bombardier, available from http://www.fjab.qc.ca/en/content/jab/biographie1926_1938.htm; Internet; accessed 29 February 2004

[66] Discontinuous innovation is defined by Miller and Morris as one that "*falls outside existing markets or market segments, and when successful extends and redefines the market, exposing new possibilities."*

[67] *Ibid*, 133

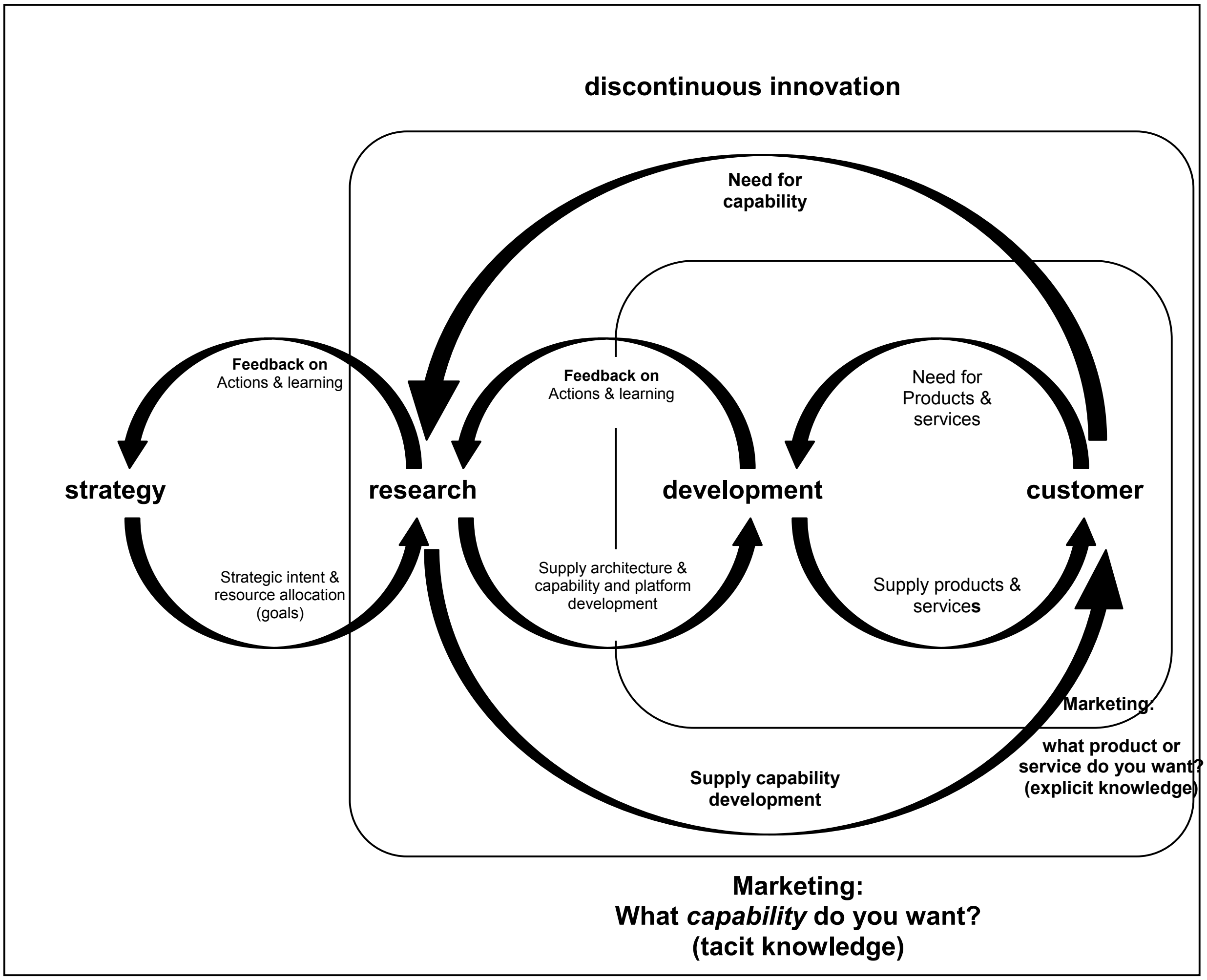

Figure 3: Discontinuous market research, reproduced from Miller & Morris

As military forces development now focuses on capabilities, one can foresee the potential benefit of adopting a new methodology based on 4th generation R&D to improve the process and maximize the chances of selecting not only pertinent technologies, but also new disruptive technologies that could potentially lead to new capabilities better adapted to the changing environment. The methodology also ensures that the pertinent technologies, by the very nature of the exploration process, will be fielded much more efficiently and rapidly than by any other conventional methods.

At the heart of the methodology reside concepts such as *knowledge channel, communities of practice, discontinuous innovation, new organizational architecture, and* *innovation processes.* It is important to mention that without a component that enables the identification (and up to a certain extent prediction) of incoming technologies, it is hopeless to keep abreast of new developments and the potential new capabilities they could offer. The knowledge channel, for example, is at the heart of the methodology, and represents a combination of both a technology watch element as well as a community of practice (experimentation) element. As previously said, most of these concepts could (and should) be adapted to the R&D management processes currently in place, as will be seen in the following sections.

Defence R&D Canada

Defence R&D Canada is the Department of National Defence Agency that was created in 2000 from the Defence R&D Branch (DRDB) that then reported to the Assistant Deputy Minister – Materiel (ADM/MAT). The Branch was by then better known by the name of its head, the Chief Research and Development (CRAD). Upon the creation of the Agency, it was decided that its CEO would not report to ADM/MAT anymore, but would rather be put at the same hierarchical level and become Assistant Deputy Minister – Science and Technology (ADM/S&T). The main reason for this change was to allow for more flexibility in the management of S&T within the department. Indeed, the Agency has evolved its structure and programmes in recent years and demonstrated new models that are more efficient and aim at "connecting" with the industry much earlier in the process than before, hence augmenting the likelihood of fielding technologies more rapidly and more economically. A brief history of the Agency can be found on their Website[68].

The model currently used by DRDC for the management of DND's R&D program could be qualified as a mix of 3rd and 4th generation R&D models as described in the previous section, although it might not yet be consciously recognized as such.

[68] Defence R&D Canada website, A Brief History of Defence R&D Canada, http://www.drdc-rddc.gc.ca/about/history_e.asp, accessed on March 23, 2004

Indeed, the formulation of the program relies strongly on a consultation process with the various elements of the CF via the Thrust Advisory Groups (TAGs) and the various Research Working Groups in place. The objective of this consultation process is really to determine the requirements of the various elements of the CF, as well as to discuss new project proposals and existing project updates. Hence the requirements are determined based on the current knowledge of the technology, and the expression by the CF of its problems and needs, which corresponds to the model used to describe the 3rd generation R&D.

However, there are some elements of the R&D program that lean towards the 4th generation model which could very well be at the heart of the new approach. The Technology Demonstration Program (TDP) is indeed such an element that will be further discussed below. A short description of the various elements of the current R&D program is included here, as well as a brief assessment of where each element stands with relation to a 4th generation R&D process. All these programs are based on the Technology Investment Strategy (TIS)[69], also briefly summarised below. More details can be obtained from the Agency website[70], as well as in the Annual Report 2002-2003 (that can also be accessed online[71]).

Technology Investment Strategy (TIS)

The Technology Investment Strategy (TIS) is the "master reference" on which most (if not all) of the decisions related to investment in technologies are based. It was developed in 1999 (and revisited in 2002) in order to establish a roadmap of the technologies that should be researched/investigated by the Agency in order to produce

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[69] Department of National Defence, "Technology Investment Strategy 2002: For The Evolving Global Security Environment", available from http://www.drdc-rddc.gc.ca/researchtech/investment_e.asp; Internet; accessed March 23, 2004.
[70] Department of National Defence, "R&D Program", available from http://www.drdc-rddc.gc.ca/researchtech/rdprogram_e.asp ;Internet; accessed March 23, 2004.

significant outcomes for national security in the coming 10-15 years. It was prepared taking into account *Defence Strategy 2020* and the new approach of the Department to Strategic Capability Planning. The TIS is based on 21 R&D Activities that range from command and control information systems, through emerging materials and biotechnologies, autonomous intelligent systems, space systems, to weapons performance and precision weapons, just to name a few.

Technology Investigation and Application Program (TI/TA)

The TI/TA program forms the scientific base of the Agency. It consists of thrusts and projects that are established upon consultation with the CF, which leads to the establishment of a Service Level Agreement (SLA) that is prepared and signed for each of the five client groups (Maritime, Land, Air, C4ISR and Human Performance). Projects generally involve a team formed with a core of R&D staff, with external partners from academia, industry and allies. A typical project lasts for five years and ranges between $3M and $6M. The total value of the program was $43M in 2002-2003. As the establishment of the projects is generally the result of consultation between DRDC scientists and CF clients, it is really managed *à la* 3rd generation R&D as previously described. It might involve some experimentation with the user, but generally on a fairly limited basis.

Technology Investment Fund (TIF)

This program involves high-risk, high-payoff research. These are the kind of projects that are often referred to as *blue-sky research* in the scientific jargon. Although they generally involve new or non-mature technologies, they nevertheless consist of applied research (as opposed to more fundamental research generally conducted in universities and academia). They also generally involve partners from both the academia

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[71]Department of National Defence, "Defence R&D Canada Annual Report 2002-2003: Opening New Doors of Innovation, http://www.drdc-rddc.gc.ca/publications/annual/0203/annualreport_e.asp, accessed on

and industry. A typical project has a three-year duration, with a total value around $1M. As the program addresses new or emerging technologies, it has the potential of playing a role in any new approach along the 4^{th} generation R&D management philosophy. At this point in time though, it does not really involve the CF client in the exploration of the technology nor in the determination of the potential requirements for the capabilities these could potentially offer. It is hence managed along the 3^{rd} generation principles and relies only on consultation with the CF client to validate the potential and the usefulness of the potential outcome. It rarely involves any experimentation with the user at all.

Defence Industrial Research Program (DIR)

The DIR program consists of the funding of projects proposed by the industry. The program allows for the funding of up to 50% of the total project, provided the total value does not exceed $1M. The company can elect to propose a project of larger magnitude, but the maximum contribution from the Agency remains capped at $500K. The total value of the program was $40M in 2002-2003, of which $15M was funded by DRDC. As this is mainly a pure funding program and generally deals with projects that are in the advanced development phase, it offers little potential for a 4^{th} generation R&D management process.

Technology Demonstration Program (TDP)

This program was established in 1999 to replace the former Major Development Program, which was outdated and needed to be replaced by a more modern approach to large R&D projects. The main characteristic of the TDP is that it is directed towards concept exploration/validation, versus the former program that was more oriented to systems and hardware development. Projects undertaken in this program can be proposed by organisations within DND, other government departments (more seldom), and Canadian industry. They generally involve several partners, and the total value of any given project is generally in the neighbourhood of $10M and has a total duration of three to five years. Total value of the program was $61M in 02-03, and it was recently increased by approximately $10M. Projects explore and evaluate advanced technologies to determine their usefulness and their utilisation concepts for optimal results. The TDP Guidebook provides complete details on the program[72].

In its current form and shape, it is the program that comes closer to the 4th generation management philosophy. Projects generally involve CF users in experimentation (usually once or twice a year) and the exploration of the potential of new or emerging technologies that are not necessarily available at the time of experimentation. A good example of such an approach in a TDP project is the Soldier Information REQuirement Technology Demonstration project (SIREQ TD) where the potential benefits of information technologies were investigated either via simulations of the technologies, or by using alternative technologies that played the role of the potential technology (*make believe*). Although it does not perfectly meet the criteria of the 4th generation model, as the CF client was not significantly involved at the very first steps of the project definition, it is not too far away as unavailable technologies can hence be investigated (via various artifices). The users participated in the experimentation that, in an evolving cycle (or spiral), contributed to the definition of the further experimentation along the next steps of the project. They also gained knowledge of the potential technology, its use, and hence could provide a well-informed opinion as to its pertinence and potential usage (doctrine as well, up to a certain extent). A follow-up project to this one was recently initiated, called Soldier Integrated Helmet System (SIHS) that will build upon the lessons learned from the predecessor project, and build on the findings for the requirements of the technologies and capabilities that were identified as having a high payoff potential to enhance the soldier's ability to fulfil their missions. Hence it is the

[72] Department of National Defence, "Technology Demonstration Program Handbook", available from http://www.drdc-rddc.gc.ca/business/tdp/tdp-guide_e.asp; Internet; accessed March 23, 2004.

author's view that this program could be put to an even better contribution in the R&D management process.

S&T Outlook

In recent years, the Agency has initiated an S&T Outlook program that aims at providing foresight of, and advise on, emerging and potentially disruptive technologies that are likely to impact the CF in the coming 10 to 25 years. The approach includes: foresight methodologies that aim at systematically looking into the longer-term future of S&T and their potential impacts on society, to identify the emerging change factors; knowledge management methodologies such as knowledge portals and communities of practice; and technology maturation modelling. The Disruptive Technology Watch Portal (DTW) was implemented at the end of 2003 to provide a tool to individuals involved with, and interested in, Defence S&T for information exchange and discussion on potentially disruptive technologies.

Although this program represents a very positive step forward, it still has to attain its full potential. Indeed, the contribution of the various players in the scientific community, and more particularly those of DRDC, is on a voluntary basis. In today's fast moving world and limited resources, it is difficult to devote the time required to contribute to these platforms, and hence their success is rather limited. It is therefore necessary to find a way to ensure that the DRDC scientists (as well as others outside DRDC, to a lesser extent) will be encouraged to contribute on a regular basis; otherwise the full benefits of such initiatives will never come to fruition.

Strategic Technology Acquisition Planning

The Agency, in support to the transformation of the CF, is also exploring and defining the concept of Strategic Technology Acquisition Planning. The program aims at identifying key technologies that will be battlefield-ready within 10 years, and determine how to bring them to the battlefield in a holistic manner[73]. Although this initiative is well aligned with the concept presented in this paper, and offers the potential of integration into the new methodology, it is still ill defined and requires much work before it can be implemented. It offers a potential advantage if it could be shaped according to the new methodology that should be integrated across the entire Agency.

Current Situation

It is opportune here to summarize the various components of what should form the management process of R&D in the department, keeping in mind the 4^{th} generation R&D management process. Table 1 presents the author's view of the most important elements but it should not be considered as a comprehensive list of all the elements required. It identifies what could be considered as existing components in the present organisations, and presents comments and questions in relation to the current status and the possible way ahead. Some of the elements do not have a one-to-one correspondence with existing elements/programs; as for example a community of practice includes both elements of experimentation as well as S&T Outlook. However, for reasons of simplicity, only the major affinities are presented in the table.

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[73] Walker, Robert, "CF/DND Transformation: the Role of DRDC", PowerPoint presentation, (September 2003), slide 24

Table 1: Status of the required and existing elements for a 4th Generation R&D Process

Element of a 4th Generation R&D Management Process	Corresponding DRDC or DND Program	Comments/Evaluation
Knowledge Channel	S&T Outlook	The main element of the Knowledge channel should be a technology watch program. The S&T Outlook exists but needs refinement and further work to take full advantage of this initiative.
Communities of practice	CFEC	Still in implementation. Could play a significant role in the experimentation that is required with the end-user, from the very beginning of the exploration of any given technology. Needs to be integrated and coordinated in the process. If CFEC cannot be adapted to play this role, it is essential to find another mechanism that will allow the involvement of end-users right at the very first step of a technology investigation.
	TDP	Currently explores mainly technologies that have been proven in concept. The connection with CFEC already exists, as there are DRDC scientists posted there. Better coordination and stronger links might be required. Can we simply add a specific project type to address the issue of exploration of emerging technology, or is a new separate and similar program required (Technology Exploration Program)?
Communities of practice (cont'd)	Strategic Technology Acquisition Planning	Although still ill defined, this program could form a strong component of the communities of practice in closing the loop from the technology identification to insertion.

Element of a 4th Generation R&D Management Process	Corresponding DRDC or DND Program	Comments/Evaluation
Chief Innovation Officer	N/A?	Seems to be missing, although part of this role is currently played by the Director S&T Policies (mainly technology watch). Does DRDC or the Department need such a champion? It seems to be an essential condition for success.

Concluding Remarks

This paper presented a brief analysis of the current R&D management programs in relation to the increasing development pace of technology and its effect on the transformation requirements of the CF. It then explores new management processes based on best practices developed mainly for the commercial sector. Despite the fact that 4th generation R&D management processes presented are tailored for private businesses, most of the principles presented are also applicable to the public sector, as well as for the R&D management for the Department of National Defence. Although most of the elements can already be found in current programs and practices, much work remains before a cohesive management process adapted to the ever faster technological evolutions can be fully implemented. It should also be noted that the process probably could (and should) be tailored to include the procurement community. They then would benefit from the knowledge and awareness acquired during the whole cycle and hence be in a much better-informed position to accomplish their tasks in the procurement phase (should the technology reach that stage).

It is the author's belief that a revised process would fulfill the desired objectives and provide an efficient way of ensuring that both DRDC and the Department will be in a position to adequately cope with the pace of technology evolution. Also, one must recognize that most of the building blocks required for the construct of the process exist at least in an initial form, and that the general tendency for R&D management already leans towards the philosophy proposed by the authors of 4^{th} Generation R&D. Integration between the various programs and CFEC (or any other organisation of DND that could be created to play this role, should it be deemed more appropriate) should be regarded as a key to ensure a successful transition to the desired process. What remains to be done is to thoroughly investigate the status of these building blocks, determine what is missing, and, above all, define a mechanism that will ensure that all the “pieces of the puzzle” work together in a synergistic manner. Establishing such a methodology should lead the CF capabilities into the future.

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