Defence Science and Technology Strategy:

An Economics Perspective

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DRDC CORA TM 2008-050
November 2008

Defence R&D Canada
Centre for Operational Research & Analysis

National Defence | Défense nationale

Canada

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Technical Memorandum
DRDC CORA TM 2008-050
November 2008

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Abstract

This paper is exploratory in nature and provides a macro-level assessment of the Department of National Defence (DND) Science and Technology (S&T) strategy. The primary tool of assessment is economics since it is the study of scarce resources, which happen to have alternate uses. Specifically, military budgets are at best constant as governments have to contend with other priorities, such as an aging population. In addition, within the S&T domain, defence research and development (R&D) have opportunity costs through the use of scarce scientific personnel and assets that could be used for civilian research.

In addition, the paper examines current Federal S&T strategies as well as previous industrial policies such as the Industrial and Regional Benefits (IRB) program to draw lessons learned. Some transaction cost economics aspects of a potential public-private partnership are also explored to provide some policy guidance.

Résumé

Cet article, de nature exploratoire, a pour objet d'évaluer dans son ensemble la stratégie du ministère de la Défense nationale (MDN) en matière de science et de technologie (S-T). Le principal instrument d'évaluation en l'occurrence est l'économique, car cette science a pour objet l'étude de la rareté des ressources, et il se trouve que celles-ci peuvent être affectées à différents usages. En particulier, les budgets militaires sont stables dans le meilleur des cas, puisque les autorités publiques doivent répondre à d'autres priorités comme le vieillissement de la population. En outre, dans le domaine de la S-T, la recherche-développement pour la défense implique des coûts d'option, car elle nécessite l'emploi de scientifiques et de ressources matérielles qui sont déjà en quantité limitée et qui seraient autrement affectés à la recherche civile.

L'article examine par ailleurs les stratégies actuelles du gouvernement fédéral en matière de S-T, ainsi que les politiques industrielles antérieures, comme la Politique des retombées industrielles et régionales, afin d'en tirer des enseignements. Enfin, l'auteur étudie le concept du partenariat public-privé sous l'aspect des coûts de transaction pour assurer une orientation stratégique.

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Executive summary

Defence Science and Technology Strategy: An Economics Perspective

Binyam Solomon; DRDC CORA TM 2008-050; Defence R&D Canada – CORA; November 2008.

Early in 2008, Centre for Operational Research and Analysis (CORA) scientists were invited to provide analytical support to a sub-project of Expedition 09. Expedition 09 is a Defence Research and Development Canada (DRDC) corporate action plan to facilitate the Defence Science and Technology (S&T) Strategy. The sub-project is on technology management and insertion with the goal of developing and demonstrating options for technology management that will assist in the seamless upgrade of Canadian Forces capabilities. While CORA continues to provide advice and support to the technology management and insertion sub-project, this technical memorandum is not addressing specific issues related to the project. The purpose of the technical memorandum is to examine the overall defence S&T strategy and to compare it with the existing Federal government S&T strategy from an economics perspective.

Economics is the ideal tool to examine government policies at the macro level because it is the study of scarce resources which happen to have alternate uses. In our present context, military budgets are at best constant as governments have to contend with other priorities, such as an aging population. In addition, within the S&T domain, defence research and development (R&D) have opportunity costs through the use of scarce scientific personnel and assets that could be used on civilian research. Basic economic tools and theories are used in this paper to examine both the federal and Department of National Defence (DND) S&T strategies. In addition, previous Government of Canada policies as well as stylized facts about S&T expenditures and trends are used to gauge the relative size within the Canadian economy. Some transaction cost economics aspects of a potential public-private partnership were also explored to provide some policy guidance.

From policy design perspective, both the Federal and DND S&T strategies stress the utilization of S&T assets to contribute to the improvement of Canadian economic performance (improve productivity) and general well being of Canadians. The Federal strategy focuses on market-based polices such as fostering competition, trade, investment, as well as designing optimal policies for intellectual property, taxation, regulation, and capital markets. Similarly, the DND S&T strategy is economic in nature, albeit at a micro level, where the strategy is designed to facilitate defence S&T assets to respond to Canadian Forces (CF) and DND priorities, institutional and core business lines. In essence, Defence S&T increases a nation's military capability by improving its national security through using technology (quality) rather than increasing the quantity of inputs such as military personnel and equipment.

The **Laissez-faire** approach of the Federal S&T strategy is generally attractive to economists for at least three reasons. First, the government sector is not in a position to know what types of innovations are required or best suited in each industrial sector. Second, providing tax incentives and direct subsidies may be costly because there is a requirement for the monitoring and evaluation of the projects and activities that qualify for the tax incentive. In addition, firms may

use the tax advantage for general purpose cost reduction if the monitoring process or the contractual arrangement is inadequate (information asymmetry). Third, the bureaucracy may have its own incentives that may be inconsistent with social welfare. For example, a bureaucrat may continue a subsidy program in order to protect budgets and jobs even if the program delivers zero social or economic benefit to the sector, region, etc. The review of the data on S&T expenditures in Canada and cross-country comparisons on Research and Development (R&D) investment revealed that the government spending on R&D was comparable to other nations of similar economic and industrial size. However, the business sector R&D spending of about 1% of GDP is considerably below most Group of Seven (highly industrialized) nations and selected developed countries such as Sweden and Australia. Since firms are profit maximizers, the lack of innovation may point to an unfavourable fiscal or legal environment. At least from the perspective of policy design, the federal strategy of a more business friendly fiscal environment is the right prescription.

The focus and scope of the defence S&T strategy are understandably narrow but most importantly, have a very specific goal of maximizing S&T returns to DND using various administrative and process improvements. Maximizing S&T returns according to the strategy is “quantified” by identifying eight outcomes that will benefit the CF/DND. These include, among others, a robust Command and Control structure, interoperability, agility, and Operational superiority through situational awareness of both the physical and social environment.

If attracting private sector partners is one of the main goals of the S&T strategy, certainly the amount of money at play is of interest. Defence S&T expenditures totalled $249M in 2007 of which about half was farmed out to the private sector. In terms of total defence expenditures, this level of expenditure is roughly 1.5%. DND’s R&D funding to the business sector is roughly $100 million or 4.5% of DND’s capital budget. Questions about the adequacy of the spending level tend to be answered through comparisons with similar nations or through opportunity costs considerations. Either method reveals that R&D, and specifically defence R&D, is not a priority item in Canada. In addition, this level of investment may not be able to attract the bigger players in the Canadian Defence Industrial Base.

Going forward with the S&T strategy and its emphasis on collaboration with industry and other partners, economic theory suggests some general recommendations on how to design an optimal contract and intellectual property rights regime. Writing the optimal contract is difficult. One cannot anticipate all unknown and unknowable future events. In addition, defence is unique for its requirement for contracts covering a long period of time or a technological superiority that demands the contractor to commit to funding costly and highly specific investments. In addition, the strategic environment is highly uncertain. In an adversarial environment of military conflict secrecy may be a key feature.

However, knowledge is a unique public good that benefits from cumulative effect and the return on investment may be reduced without the interactive environment. The key to a good IPR is that it is not too strong to deter cooperation or constrain incentives and not too weak to leave the public with no benefit from its investment in S&T. It should allow both parties to mange risks and secure their respective share of future returns.

The general impact of R&D spending, whether civil or defence, on the macro economy is also assessed in this study. The consensus is that civilian R&D spending does improve a nation’s productivity and by extension, its standard of living. The same cannot be said for defence, however. Since the benefits of defence R&D are ethereal (such as the betterment of national defence and security), it is difficult to construct quantifiable proxies. In addition, recent studies seem to point out that defence R&D may crowd out private investment in R&D. The most important result to draw from these studies is that a Canadian specific assessment is absent from the literature and such Canada-specific studies are warranted to make an informed policy choice.

Thus future studies should look at the macro and micro economic implications of defence R&D and the partnership types that elicit the optimal R&D participation from non-governmental entities. To the extent that defence R&D is about quality as opposed to quantity in capabilities investment, an empirical study on the effect of previous R&D investment on the quality and capability of the CF assets should be explored. There are also data quality issues that need to be addressed before embarking on a detailed empirical assessment.

Sommaire

Defence Science and Technology Strategy: An Economics Perspective

Binyam Solomon; DRDC CORA TM 2008-050; R & D pour la défense Canada – CORA; Novembre 2008.

Au début de 2008, les scientifiques du Centre d'analyse et de recherche opérationnelle (CARO) ont été invités à fournir des services d'analyse pour un sous-projet de Expédition 09. Expédition 09 est un plan d'action général de Recherche et développement pour la défense Canada (RDDC) qui vise à faciliter la mise en œuvre de la stratégie de science et technologie (S-T) pour la défense. Le sous-projet a trait à la gestion et à l'intégration de la technologie et il a pour objectif d'élaborer et d'exposer des options de gestion de la technologie qui permettront d'améliorer sans heurts les capacités des Forces canadiennes. Si le CARO continue de fournir des conseils et du soutien pour ce sous-projet, ce document technique ne traite pas des questions particulières liées à ce projet. Il a plutôt pour objet d'examiner dans son ensemble la stratégie de S-T pour la défense et de la comparer à celle du gouvernement fédéral dans un cadre d'analyse économique.

L'économique est l'instrument idéal pour examiner les politiques de l'État à l'échelon global, parce que cette science a pour objet l'étude de la rareté des ressources, et il se trouve que celles-ci peuvent être affectées à différents usages. Dans la conjoncture actuelle, les budgets militaires sont au mieux stables, puisque les autorités publiques doivent répondre à d'autres priorités comme le vieillissement de la population. En outre, dans le domaine de la S-T, la recherche-développement pour la défense implique des coûts d'option, car elle nécessite l'emploi de scientifiques et de ressources matérielles qui sont déjà en quantité limitée et qui seraient autrement affectés à la recherche civile. Dans cet article, nous examinons les stratégies de S-T du gouvernement fédéral et du ministère de la Défense nationale (MDN) à l'aide des principes et des instruments fondamentaux de la science économique. Nous évaluons en outre le poids relatif des activités de S-T dans l'ensemble de l'économie canadienne en nous fondant sur les politiques antérieures du gouvernement du Canada et les faits stylisés concernant les dépenses et les tendances en matière de S-T. Enfin, nous étudions le concept du partenariat public-privé sous l'aspect des coûts de transaction pour assurer une orientation stratégique.

Du point de vue de l'élaboration des politiques, les stratégies de S-T du gouvernement fédéral et du MDN insistent toutes deux sur l'utilisation des ressources en S-T pour améliorer la performance économique du Canada (notamment la productivité) et le mieux-être des Canadiens. La stratégie fédérale met l'accent sur des politiques axées sur le marché, par exemple favoriser la concurrence, le commerce et l'investissement, et élaborer des politiques optimales concernant la propriété intellectuelle, la fiscalité, la réglementation et les marchés des capitaux. De même, la stratégie de S-T du MDN a une orientation économique, ou plutôt microéconomique, et elle a pour objet de favoriser l'utilisation des ressources en S-T de la défense pour répondre aux priorités des Forces canadiennes (FC) et du Ministère tant sur le plan institutionnel qu'en ce qui concerne les activités essentielles. Fondamentalement, la stratégie de S-T pour la défense accroît la capacité militaire d'un pays en améliorant sa sécurité nationale par le moyen de la technologie (qualité) plutôt qu'en augmentant la quantité de ressources (personnel militaire, matériel).

L'approche de **laissez-faire** qui caractérise la stratégie de S-T du gouvernement fédéral est généralement intéressante aux yeux des économistes pour au moins trois raisons. Premièrement, le secteur public n'est pas en mesure de savoir quels types d'innovations sont nécessaires ou conviennent le mieux pour chaque secteur industriel. Deuxièmement, offrir des stimulants fiscaux et des subventions directes peut être une solution coûteuse, parce qu'il faut surveiller et évaluer les projets et les activités qui remplissent les conditions requises pour l'octroi d'incitatifs fiscaux. En outre, il y a toujours la possibilité que des entreprises profitent de ces avantages pour réduire leurs coûts en général, si le processus de surveillance laisse à désirer ou si l'entente contractuelle est imparfaite (information asymétrique). Troisièmement, la bureaucratie peut avoir ses propres motivations qui seront peut-être incompatibles avec le bien-être collectif. Par exemple, un fonctionnaire pourrait maintenir un programme de subvention dans le seul but de préserver les crédits budgétaires et les emplois qui s'y rattachent, même si ce programme ne rapporte aucun avantage économique ou social pour le secteur, la région, etc. Un examen des données sur les dépenses en S-T au Canada et une comparaison des niveaux d'investissement en recherche-développement (R-D) entre différents pays révèlent que le niveau des dépenses publiques en R-D au Canada est comparable à celui observé dans des pays qui affichent le même niveau d'activité économique et industrielle que le Canada. Toutefois, le niveau des dépenses en R-D du secteur privé au Canada, qui compte pour environ 1 % du PIB, est bien au-dessous de celui observé dans la plupart des pays du Groupe des Sept (pays les plus industrialisés) et certains pays développés comme la Suède et l'Australie. Comme les entreprises sont naturellement des maximiseurs de profit, l'absence d'innovations peut révéler l'existence d'un contexte financier ou juridique défavorable. Du point de vue de l'élaboration des politiques à tout le moins, la stratégie fédérale qui consiste à instaurer un climat financier plus propice à l'investissement des entreprises est une bonne solution.

La stratégie de S-T pour la défense a un objet et un champ d'application naturellement plus limités, mais — aspect le plus important — elle a un objectif très précis, qui est de maximiser les rendements de la S-T pour le Ministère en améliorant les processus administratifs ou autres. On peut « quantifier » cet objectif en définissant huit critères de résultat dont la réalisation profitera aux Forces canadiennes et au Ministère; parmi ces critères on note une solide structure de commandement et de contrôle, l'interopérabilité, la flexibilité, et l'efficacité opérationnelle par une connaissance tactique du milieu physique et social.

Si l'un des principaux objectifs de la stratégie de S-T est de susciter l'intérêt de partenaires éventuels du secteur privé, les montants en jeu ont de quoi attirer l'attention. En effet, les dépenses en S-T pour la défense ont totalisé 249 millions de dollars en 2007, dont environ la moitié est allée au secteur privé par voie de sous-traitance. Ce montant représente environ 1,5 % des dépenses totales de défense. Les dépenses en R-D du Ministère allouées au secteur privé s'élèvent à 100 millions de dollars environ, soit l'équivalent de 4,5 % du budget d'équipement du Ministère. Quant à savoir si le niveau des dépenses en R-D au Canada est suffisant, on le vérifie généralement en comparant le Canada avec des pays semblables ou en examinant la question sous l'angle des coûts d'option. L'une et l'autre méthodes indiquent que la R-D, et plus particulièrement la R-D pour la défense, n'est pas un objectif prioritaire au Canada. En outre, le niveau d'investissement considéré ne suffit peut-être pas pour attirer les plus gros acteurs dans le complexe industriel canadien de défense.

Si on met de l'avant la stratégie de S-T, avec son principe de la collaboration avec les entreprises industrielles et d'autres partenaires, la théorie économique présente des recommandations générales sur la façon optimale d'établir un contrat et d'instaurer un régime de droits de propriété intellectuelle. Rédiger un contrat de façon optimale est certes difficile. On ne peut prévoir tous les événements. De plus, le domaine de la défense revêt un caractère unique du fait qu'il exige des contrats à long terme et un degré de compétence technologique supérieur, de sorte que l'entrepreneur est obligé de financer des investissements coûteux et très pointus. Par surcroît, l'environnement stratégique est très incertain. Lors d'un conflit militaire, par exemple, le secret peut être un élément clé.

Il n'en reste pas moins que les connaissances sont un bien public unique qui bénéficie de l'effet cumulatif et que le rendement de l'investissement peut être réduit sans que l'environnement interactif y soit pour quelque chose. La condition essentielle pour qu'un régime de droits de propriété intellectuelle soit intéressant est d'être ni trop sévère, pour éviter de décourager la participation des entreprises et de restreindre les incitatifs, ni trop faible, pour éviter que la population ne retire aucun avantage de l'investissement public en S-T. Un tel régime devrait permettre aux deux parties de gérer les risques et de recevoir leur part respective des rendements futurs.

La présente étude examine aussi l'incidence générale des dépenses en R-D — du domaine civil ou militaire — sur les facteurs macroéconomiques. On s'entend pour dire que les dépenses en R-D du domaine civil influent à la hausse sur la productivité d'un pays et, par extension, sur le niveau de vie de ses habitants. On ne peut en dire autant de la R-D pour la défense. Comme les avantages de cette activité de R-D sont éthérés (p. ex. amélioration de la défense et de la sécurité nationales), il est difficile de construire des indicateurs quantifiables. De plus, des études récentes semblent indiquer que la R-D pour la défense évincerait l'investissement privé en R-D. La principale conclusion à tirer de ces études est que la littérature ne contient aucune évaluation portant spécialement sur le Canada et que ces études sont pourtant nécessaires à une prise de décisions éclairée.

C'est pourquoi on examinera dans des études futures les incidences macroéconomiques et microéconomiques de la R-D pour la défense, ainsi que les modes de partenariat qui favorisent une participation optimale des entités non gouvernementales sur le plan de la R-D. Dans la mesure où la R-D pour la défense est orientée sur la qualité plutôt que sur la quantité (accroissement des capacités), on peut envisager la possibilité de faire une étude empirique sur l'incidence des investissements antérieurs en R-D sur la qualité et la capacité des ressources des Force canadiennes. Il faudrait aussi se pencher sur les questions touchant la qualité des données avant d'entreprendre une étude empirique détaillée.

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Acknowledgements

The author would like to acknowledge Dr. C. Boulet, Paul Massel, Dr. Roy Mitchell and Cdr. Richardson-Prager for their helpful comments and suggestions.

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1 Introduction

1.1 Background

It is well recognized that science and technology contribute to the country's ability to generate economic growth and indirectly to a nation's standard of living by improving productivity. Despite the generally rosy economic fundamentals of Canadian economy (stable growth, fiscal surpluses since 1997 and positive trade balance), the average Canadian living within 300 km of the United States is acutely aware of the slippage in the relative standard of living against their American counterpart (Rao, et al., 2005; Pilat, 2005). This deterioration in living standards has a lot to do with the relative decline of Canadian labour productivity compared to the United States (US).

At the heart of both the Federal government and Department of National Defence (DND) respective Science and Technology (S&T) strategies is the utilization of S&T assets to contribute to the improvement of Canadian economic performance (improve productivity) and general well being of Canadians. The Federal strategy focuses on market-based polices such as fostering competition, trade, investment, as well as designing optimal policies for intellectual property, taxation, regulation, and capital markets. Similarly, the DND S&T strategy is economic in nature, albeit at a micro level, where the strategy is designed to facilitate defence S&T assets to respond to Canadian Forces (CF) and DND priorities, institutional and core business lines. In essence, Defence S&T increases a nation's military capability by improving its national security through using technology (quality) rather than increasing the quantity of inputs such as military personnel and equipment.

The purpose of this paper is to critically examine the Defence S&T strategy from an economics perspective. Economics is the ideal tool to examine government policies at the macro level because it is the study of scarce resources which happen to have alternate uses. In our present context, military budgets are decreasing as governments have to contend with other priorities such as an aging population. In addition, within the S&T domain, defence research and development (R&D) have opportunity costs through the use of scarce scientific personnel and assets that could be used on civilian research.

1.2 Aim/ Objective

The scope of the study is strategic and as such does not cover operational and tactical level processes such as Technology Management or Technology Insertion. Undoubtedly, these processes have benefits and costs that also require critical scrutiny. However, the assessment of the overall S&T strategy that spawns these operational level processes needs to make economic sense before tackling any of its components. While the focus is on the Defence S&T strategy, this paper's analysis and results can be applied to the Federal government's own S&T strategy as well. In addition this paper examines some of the broader policy prescriptions of the defence S&T strategy and its efficacy given the incentives of the various players engaged in S&T namely federal agencies, industry and academia.

1.3 Document Structure

The paper is organized as follows. In the next section, stylized facts about S&T activity in Canada are presented to set the context within which the S&T strategy is developed. The section also examines the characteristics of the Canadian defence Industrial Base and its potential as an S&T partner. Section 3 presents the economic literature as it pertains to S&T and the implications of the theory to the policy prescriptions outlined in the defence S&T strategy. Section 4 presents some key economic concepts that have direct implications on policy design and S&T. The final section concludes the study and presents some recommendations.

2 Stylized Facts

The purpose of this section is to contextualize the S&T strategy by analyzing the trends in Canadian S&T spending as well as by assessing the size and characteristics of the Canadian Defence Industrial Base (CDIB) the main partner and recipient of the Federal and DND S&T activities. The implications derived from the trend analyses will inform whether a policy is warranted and if so how it should be tailored to maximize the social return from the policy investment.

2.1 Science and Technology Spending in Canada

As pointed out earlier, S&T is an important contributor to a nation's competitiveness and ultimately to the standard of living (through the improvement of productivity). There are a number of ways governments can facilitate S&T activities in a nation. Confining our analysis to the defence sector, a government agency can:

1. Directly contract S&T activity;

2. Sponsor a design competition where a winner will be guaranteed subsequent development and procurement contracts; or

3. Subsidize independent S&T work.

In 2007, Canadian S&T expenditures totalled $25B in constant dollars (removing the effects of inflation). S&T expenditures in this context include both S&T funding and performance. For the purpose of this study, most of the data has been extracted from Statistics Canada sources which use international convention and define S&T as R&D and Related Scientific Activity (RSA)[1]. Of this amount the business sector accounted for about $14B and the government and higher education institutions contributed approximately $4.6 and $4B respectively. These three entities accounted for more than 80% of the nations S&T activity. Over the last 10 years, the contribution of the government, business and higher education sectors have remained relatively stable with about 48% attributed to the business sector while the government and higher education sectors contributed 18% and 15% respectively. It should be pointed out that foreign entities were responsible for an average of 10% of the S&T activity during the last 10 years while the remaining 9% is attributed to the non-profit sectors and provincial government entities (Figure 1).

[1] Activities such as conducting surveys, generating and disseminating scientific knowledge are including under this general heading.

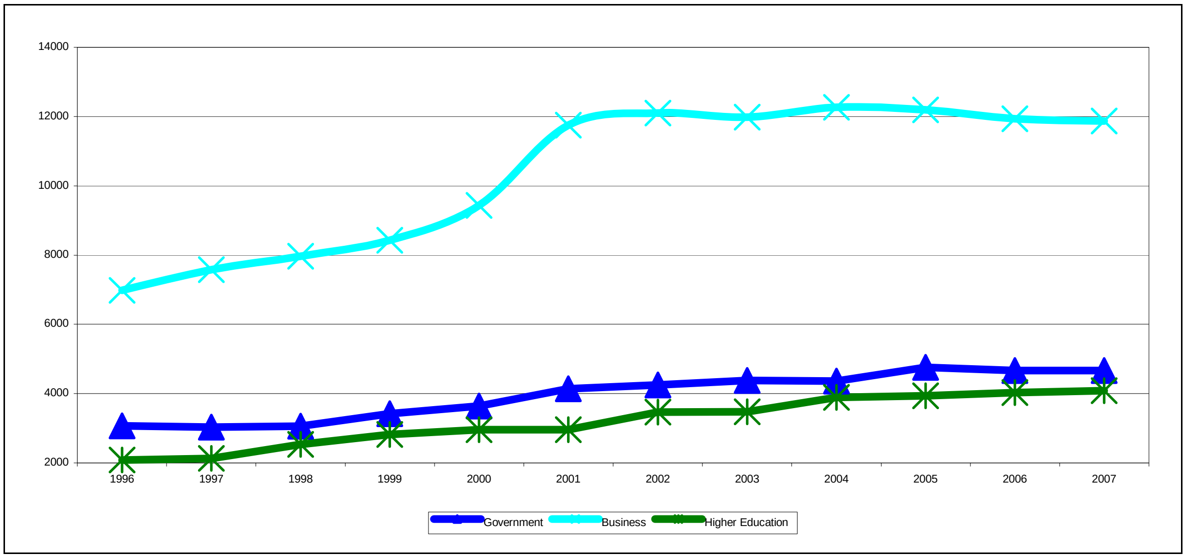

Figure 1: Total S&T Activity by Sector (Constant $Millions).

As depicted in Figure 1, S&T growth (constant dollars) has levelled off in all sectors after 2001 and in fact has declined for both the government and business sectors since 2005. Table 1 compares the same S&T expenditures to the size of the Canadian economy to gauge its relative importance. Total S&T expenditures in the last four years averaged about 2% of Gross Domestic Product (GDP) while business sector S&T activity was about 1% of GDP. For all sectors considered (Government, business and higher education) the share has remained fairly stable during the period 2003-2006.

In Table 2, the trend analysis is expanded to include other nations that are comparable to Canada in industrialization and other economic indicators such as standard of living. Compared to the Group of 7 (G7- Canada, France, Germany, Italy, Japan, United Kingdom-UK and US) countries Canada's business sector R&D expenditures share is 5th largest ahead of Italy and the UK. Canadian share is also comparatively higher than Australian and Dutch spending but is half of Swedish spending. Not surprisingly, Sweden is often ranked as one of the most productive nations in the world.

Table 1 Total S&T Activity as % of GDP by Sector Selected Years

Year	Total S&T Expenditures	Government	Business Sector	Higher Education
2003	2.0%	0.4%	1.0%	0.3%
2004	2.1%	0.4%	1.0%	0.3%
2005	2.0%	0.4%	1.0%	0.3%
2006	1.9%	0.4%	0.9%	0.3%

Source: Statistics Canada 2007 Gross Expenditures on R&D

Table 2 Business Sector R&D Expenditures as a % of GDP Selected Countries

Year	Australia	Canada	France	Germany	Italy	Japan	Netherlands	Sweden	United Kingdom	United States
2001		1.05	1.19	1.62		2.28	0.94	3.04	0.84	1.87
2002	0.86	1.05	1.16	1.63		2.35	0.86		0.80	1.74
2003		0.99	1.10	1.67		2.39	0.90	2.57	0.76	1.71
2004	0.94	0.99	1.13	1.66		2.37			0.76	1.65
2005		0.95	1.12	1.68	0.44	2.53		2.55	0.75	1.68
2006		0.92								1.70

Source: OECD Science and Technology Indicators 2007

The cross country comparisons is further expanded to look at the government sector, particularly defence R&D, as a proportion of overall government sector R&D (Table 3). In this instance, Canada's share is below every G7 nation except Italy for the period 2001 to 2006. Outside the G7, Canada's share is similarly low, with Swedish and Australian rates reaching 2-5 times higher.

2.1.1 Government Sector

In constant dollar terms, Federal spending on S&T activities totalled about $8.2B in Fiscal Year (FY) 2006/07. This is an increase of about 20% over the period 2000 to 2007. The growth in S&T expenditures varied considerably within the Federal agencies. For example, the Social Sciences and Humanities Research Council (SSHRC), the main Federal vehicle for granting S&T funding in the Social Sciences, grew by 276% to $557 Million in real terms while the Fisheries and Oceans department saw its S&T budget decrease by 35% to $243 Million during the same period. DND's S&T spending grew by a modest 13% during the period 2000-2007 and is the ninth largest department in terms of S&T spending (Table 4).

Table 3 Defence R&D Expenditures as a % of Government R&D Spending Selected Countries

Year	Australia	Canada	France	Germany	Italy	Japan	Netherlands	Sweden	United Kingdom	United States
2001	6.64	4.23	22.81	7.37	4.03	4.30	1.87	14.63	30.46	50.49
2002	6.68	3.68	22.96	5.46		4.05	1.83	21.61	33.91	52.14
2003	6.23	3.77	22.90	6.52		4.47	1.90	20.71	31.88	54.89
2004	6.65	3.75	22.20	5.84		5.14	1.33	16.64	31.02	55.71
2005	6.69	3.68	20.84	5.75	3.63	4.04	2.22	17.43	28.30	56.87
2006	7.03	3.57	22.38	6.40	1.36	5.14	2.08	16.85	28.30	57.89

Source: OECD Science and Technology Indicators 2007

Table 4 Federal science and technology (S&T) spending by major department or agency

(2000-2007 in Constant Dollars)

Fed Expenditure on S&T	2000/2001	2001/2002	2002/2003	2003/2004r	2004/2005r	2005/2006p	2006/2007p
NSERC	1	594	653	709	758	789	804
CIHR	401	535	628	671	712	697	720
Stat Can	589	735	579	563	572	681	704
NRC	670	727	793	753	744	729	702
SSHRC	148	366	188	445	491	521	557
Environment	490	633	574	751	633	575	534
Resources	447	560	511	630	593	466	441
CFI	192	242	332	353	254	403	393
DND	322	318	358	390	403	391	365
Industry	343	695	424	420	400	408	335
CIDA	366	391	352	354	389	339	334
CDN Space	317	334	320	260	259	260	331
Agriculture	371	341	320	323	319	328	302
Health	234	314	342	321	266	278	283
Fisheries	375	322	363	274	273	253	243
AECL	139	180	147	173	139	165	178
IDRC	86	77	86	86	101	106	108
Genome		34	62	83	80	84	55
Others	786	860	982	924	995	929	864
Total	**6856**	**8258**	**8014**	**8486**	**8380**	**8403**	**8253**

Source: Statistics Canada 2007b, author's Calculation p (projected), r (revised)

As discussed earlier, S&T spending includes both R&D and RSA. In terms of R&D, the Federal government spending reached $5B (constant dollars) in 2007. Most of the R&D activity in the Federal government is concentrated in a handful of agencies. The top five agencies, The Canadian Institute for Health Research (CIHR), the granting councils for the Natural and Social Sciences (NSERC, SSHRC), the Canadian Foundation for Innovation (CFI), and the National Research Council (NRC), accounted for over half the Federal R&D activity. Furthermore, the top 10 agencies accounted for more than 80% of the total spending (Table 5).

Table 5 Federal Research and Development (R&D) spending by major department or agency

(2000-2007 in Constant Dollars)

Federal Expenditure R&D	2000/2001	2001/2002	2002/2003	2003/2004r	2004/2005r	2005/2006p	2006/2007p
CIHR	393	528	622	665	702	688	711
NSERC	511	523	573	618	662	690	700
NRC	604	652	718	677	648	645	622
SSHRC	107	329	148	389	416	431	458
CFI	192	242	332	353	254	403	393
CDN Space	305	320	309	248	247	247	316
Industry	294	508	371	364	307	340	262
Resources	397	339	285	407	355	277	261
DND	280	284	261	273	278	282	249
Agriculture	362	333	267	244	232	231	207
Environment	148	224	207	256	196	209	194
AECL	139	180	147	173	139	165	178
IDRC	78	66	67	64	77	81	82
Fisheries	133	124	141	69	69	73	69
CIDA	58	57	53	60	80	58	61
Genome		34	62	83	80	84	55
Others	241	301	364	346	375	331	296
Total	**4242**	**5043**	**4927**	**5288**	**5116**	**5235**	**5115**

Source: Statistics Canada 2007b, author's Calculation p (projected), r (revised)

The purpose of R&D within the defence department is to use science and technology to improve the capabilities and effectiveness of the Canadian Forces. The program is carried out by a combination of in-house sources at seven Defence Research and Development Canada Centers and by contracting out to Canadian industry, universities and other government departments. The Assistant Deputy Minister (Science and Technology) is responsible for the conduct and management of the R&D program in defence science and technology. DND's spending of $249M is ranked the 9th highest. In terms of the growth trends, the variation among the agencies was considerable. While the SSHRC grew by a remarkable 327% during the period 2000-2007, DND and Industry Canada's spending declined by 11% during the same period. The steepest decline occurred at Agriculture Canada and Fisheries and Oceans at 43 and 48% drop respectively.

Table 6 Federal Extramural Science and Technology (S&T) spending by major department or agency (2000-2007 in Constant Dollars)

Extra S&T	2000/2001	2001/2002	2002/2003	2003/2004r	2004/2005r	2005/2006p	2006/2007p
CIDA	242	424	321	313	257	277	220
CDN Space	123	154	133	163	141	156	194
Industry	104	135	114	115	111	78	137
DND	169	168	161	146	128	143	135
NRC	91	83	76	79	78	70	71
Others	138	157	193	190	204	189	169
Total	**867**	**1120**	**998**	**1006**	**918**	**913**	**926**

Source: Statistics Canada 2007b, author's Calculation p (projected), r (revised)

Another activity of interest for our study is the Federal government's extramural science and technology (S&T) expenditures, that is, expenditures outside its own laboratories. In 2006/2007, the federal government earmarked $4.4 billion, or 47% of its total science and technology (S&T) spending, to extramural activities. Of this amount, business enterprises received $1 billion or 11% of the total Federal government S&T expenditures. The breakdown by Federal agencies revealed that extramural activities with business sector are highly concentrated with only five Federal agencies accounting for over 80% of the extramural activity (Table 6). The five agencies include NRC, DND, the Space Agency, Industry Canada and the Canadian International Development Agency (CIDA). In terms of R&D, the same agencies excluding CIDA accounted for approximately 82% of the Federal R&D money allocated to the Business sector. In terms of the trend over the last 7 years, R&D funding to the business sector has remained flat. DND's business sector R&D funding declined by 12% and NRC's by 22% during the period 2000-2007 (Table 7).

Table 7 Federal Extramural Research and Development (R&D) spending by major department or agency (2000-2007 in Constant Dollars)

R&D Extra	2000/2001	2001/2002	2002/2003	2003/2004r	2004/2005r	2005/2006p	2006/2007p
Industry	242	424	321	312	256	276	220
CDN Space	102	133	111	113	109	76	135
DND	110	123	72	95	70	63	97
NRC	91	83	76	79	78	70	71
Others	92	108	147	146	147	123	112
Total	**638**	**871**	**727**	**746**	**660**	**608**	**634**

Source: Statistics Canada 2007b, author's Calculation p (projected), r (revised)

The person-years devoted to scientific activities in the Federal Government has remained fairly stable over the first half of the 90s before decreasing by about 16% in the latter half of the decade. During the period 2000 to 2007, personnel involved in S&T activity increased by 13% to more than 36,000, while those who work exclusively in R&D declined by 3% to about 14,000 during the same period (Table 8). Of the total personnel engaged in Federal S&T, about 16,000 are classified as Professional and Scientific personnel. However only 6,000 of these professional personnel conducted R&D work in 2007. In general, only about 17% of the total Federal S&T workforce is classified as Scientific and Professional and work exclusively in R&D activity. The number of these personnel has remained fairly stable during the period 2000 to 2007, while in the RSA community the share of Professional and Scientific personnel has increased by a healthy 26% (Table 8).

Table 8 Federal personnel engaged in science and technology (S&T) activities, by department or agency.

	2000/2001	**2001/2002**	**2002/2003**	**2003/2004r**	**2004/2005r**	**2005/2006p**	**2006/2007p**
Total S&T	**32,139**	**34,035**	**35,125**	**34,707**	**34,339**	**35,182**	**36,339**
Scientific& Professional	12,540	13,098	14,481	14,823	14,928	15,205	15,806
Technical	7,854	8,635	8,905	9,003	8,884	9,081	9,271
Admin Support	11,745	12,302	11,739	10,882	10,527	10,896	11,263
Total R&D	**14,702**	**13,739**	**13,966**	**13,585**	**13,719**	**14,123**	**14,217**
Scientific	6,125	5,606	6,190	6,105	5,977	6,140	6,213
Technical	3,815	3,782	3,773	3,769	3,731	3,886	3,898
Administrative	4,762	4,351	4,003	3,711	4,012	4,097	4,107

Source: Statistics Canada 2007b, author's Calculation, p (projected), r (revised)

2.1.2 Industrial Sector

At the industrial level, the R&D statistics show a small number of industries are responsible for half the R&D in Canada. Specifically, industries associated with information and culture (software film, music, etc) accounted for $1.7B or 20% of total R&D spending in Canada in 2007 (See Table 9). The communication equipment manufacturing industries (Nortel is the leading firm) accounted for 9% of total R&D or about $1.4B, while the computer system design and scientific R&D services industries[2] each accounted for 8% of total expenditures or about $1.3B during the same year. The pharmaceutical and medicine sector spent $1.1B and the aerospace products and parts about $1B in 2007, which represented 7 and 6.5% respectively of total R&D expenditures.

[2] This industry group comprises establishments primarily engaged in conducting original investigation, undertaken on a systematic basis to gain new knowledge (research), and in the application of research findings or other scientific knowledge for the creation of new or significantly improved products or processes (experimental development).

Table 9 Research and Development (R&D) Expenditures by Industry 2003-2007 $Millions

	2003 r	2004 r	2005 p	2006 p	2007 p
Total all industries	**14,039**	**14,947**	**15,356**	**15,360**	**15,773**
Total agriculture, forestry, fishing and hunting	**94**	**96**	**109**	**x**	**x**
Total mining and oil and gas extraction	**283**	**333**	**409**	**398**	**368**
Construction	**x**	**53**	**66**	**63**	**64**
Total manufacturing	**8,140**	**8,177**	**8,224**	**8,095**	**8,316**
Pharmaceutical and medicine	1,110	1,189	1,221	1,129	1,145
Communications equipment	1,698	1,509	1,386	1,392	1,433
Semiconductor and other electronic components	743	808	832	857	917
Navigational, measuring, medical and control instruments	351	366	469	416	385
Aerospace products and parts	891	x	x	963	1,021
Other manufacturing industries	3,347	4,305	4,316	3,338	3,415
Total services	**5,343**	**6,045**	**6,287**	**6,445**	**6,667**
Information and cultural industries	1,124	1,346	1,545	1,654	1,671
Computer system design and related services	1,119	1,152	1,134	1,212	1,265
Scientific research and development services	937	1,209	1,183	1,214	1,267
All other services	2,163	2,338	2,425	2,365	2,464
Total Expenditures as % of Gross Domestic Product	1.2%	1.2%	1.1%	1.1%	

Source: Statistics Canada 2007 Gross Expenditures on R&D p (projected), r (revised)

Over the last five years (2003-2007), the R&D expenditures pattern of these industrial sectors have been stable with the exception of the information and culture sector growing its share of R&D expenditure from about 14 to 20%, and the communication equipment sector declining from a share of 12% to the current 9%. Compared to other Organization for Economic Co-operation and Development (OECD) countries the level of R&D expenditures (roughly 1% of GDP) puts Canada in the middle rank and 5th among the G7 countries behind the US, Japan, France and Germany and ahead of the UK and Italy (as noted in Table 2).

At the firm level, Canadian R&D activity tends to be dominated by foreign subsidiaries and pharmaceuticals firms. While most defence firms tend to be relatively R&D intensive, particularly those in the US and Europe, this does not seem to be the case for the Canadian Defence Industrial base (CDIB). While the CDIB will be discussed in some detail in the next section, the firm level R&D activity reveals some insights on the size and characteristics of the sector. Foreign subsidiaries of US aerospace firms (such as Pratt & Whitney Canada, and Honeywell Canada) do show up in the top 100 R&D firms list in Canada but information technology (IT) and pharmaceutical companies often dominate the list. About 55% of the top 100 R&D spending was due to IT firms with Nortel accounting for the lion's share. The CDIB is represented by 5 Aerospace companies and as a group accounted for 7% of total spending, led by

Pratt & Whitney Canada with $481million of R&D (Table 10). The Canadian aerospace industry's investment in R&D totalled $886 million in 2006.

Table 10 Top CDIB R&D Spenders in Canada

2006 Rank	Company Name	2006 RD Expenditures	Revenue $Mil. 2006	R&D as % of Revenue
1	Nortel	2199	12,949	17
4	Pratt & Whitney Canada Inc (fc)	481	3000	16
9	Bombardier Inc.	196	16,802	1.2
26	CAE Inc.	96	986.2	10.9
34	Honeywell Canada (fc)	68	1302	7.1
54	MacDonald Dettwiler and Assoc.	44.5	832.9	5.9

Source: Research Infosource Inc. 2006 FC-Foreign Parent Company

2.2 Economic Implications

The expenditure data and trend analyses of the preceding sections provide a reasonable snapshot on the state of R&D spending in Canada. However, the relevant question that has yet to be answered remains: what are the economic significance and implications of the data and analyses thus far? The answer to this question should also assist us in shaping an effective R&D policy.

From an economics perspective, the preceding discussion on data and trends leads to the following three questions. First, is the level of R&D spending in Canada adequate to attract industry's interest? Second, does the government sector's S&T activity siphons scarce scientific resources? And finally, given the size and distribution of R&D activity in the wider economy, is a policy (federal or DND) necessary?

2.2.1 Level of R&D Spending

As mentioned in the introductory section, R&D activities contribute to the enhancement of productivity and overall standard of living in a given nation. Assuming this link is true, the private sector will maximize the return from R&D given its cost and production profile. This is the standard economics assumption of the profit maximizing firm. There is also an implicit assumption that the firm is operating in a relatively competitive market where innovation is a necessity to remain viable. In a less competitive market, firms may still use R&D to maintain market share but in general a competitive market place does provide a more fertile ground for innovation.

For a welfare maximizing government agent, there are two avenues to foster R&D spending. It can either fund its own R&D or subsidize private sector R&D. The former can also be done to improve service delivery within the government or if the R&D activity results in a pure public good. A pure public good is a product or service that has two distinct aspects—"non-excludability" and "non-rivalrous consumption." Non-excludability means that a firm or entrepreneur cannot exclude people from enjoying the product or service. A popular example in economics is fireworks. Anyone who is a reasonable distance from the firework show can enjoy the display without paying for it. Since the firm or the entrepreneur cannot charge a fee for consumption, the fireworks show may not occur, even if demand for the show is strong. Some include pure research and development a public good since other firms will free ride on the innovation by copying or further developing the original idea. The other aspect of public good is that it is non-rival. Here, consider a cable company that charges its customers for access to its programs. Without scrambler technology, exclusion is inefficient because even non-payers could watch the show without increasing the show's cost or diminishing anyone else's enjoyment.

However, the choice of the cable company example is deliberate in that not all public goods point to market failure and consequently government intervention. The scrambler technology allows the private sector to produce cable programs since they can exclude non payers. Similarly, the market economy may deliver pure public R&D activities if the government creates the right legal (Intellectual Property) and fiscal (taxes and regulations) environment.

Using these economic principles as a gauge, the following observations and generalization can be discerned from the trend analysis discussed above.

1. The business sector R&D spending of about 1% of GDP is considerably below most G7 countries and selected developed countries such as Sweden and Australia. Since firms are profit maximizers, the lack of innovation may point to an unfavourable fiscal or legal environment.

2. The government sector R&D is comparable to most developed nations including the G7. However, the declining trend in public funding of business R&D is puzzling especially given the policy of increasing public private partnerships.

3. Ultimately, the question of how much to spend on R&D is based on its opportunity cost. This is especially true of defence versus other civilian R&D.

2.2.2 The Competition for Talent

The data discussed in the preceding sections are highly aggregate to assess whether there is competition for scarce scientific resources. However, using Census 2001 data and the education variable in particular, one can examine whether the Federal government siphons scientific personnel by bidding up the price (wages and compensation). The Census 2001 data is primarily used to compare major industrial aggregates and the sectors that are normally associated with defence procurement.

In general, the average salary in all industries in Canada was about $32,000 in 2001 while in the government sector it ranged from $44,000 (Federal government excluding defence) to $36,000 for local government. In terms of the scientific and professional personnel in the physical science and mathematics, the overall Canadian industry average was 2% of the labour force. The government sector average was broadly similar to the industry average except the non-defence Federal government, which has a slightly higher (4%) proportion of its labour force in the scientific fields.

A look at the 2001 census on education attainment of the labour force by industry (specifically, Bachelor's degree or above in Engineering and applied science) seems to confirm an earlier Parai and Solomon (1992) finding, especially for the shipbuilding, military vehicles (railroad rolling) and firearms (Metal fabricating) industries. These industries had percentages of university educated labour force below the national average. Other CDIB sectors such as the Aerospace industry, ammunition (chemical) and defence electronics (communication and other electronics) showed averages of educated workforce at or above the total national industry level. It should be acknowledged that the industry aggregation in the census data tends to aggregate the CDIB with other civilian firms and as such the results are unavoidably distorted (See Table A-11 and A-12, Annex A).

Despite the caveat, however, some general observations can be provided. First comparing the CDIB to other so called "Hi-Tech" industries such as Information Technology and professional management services (engineering, legal and other services), the percentage of the labour force with university education is substantially higher in the "Hi-Tech" sector than in the CDIB and the Canadian average. Second, within the educational attainment category of the 1996 census data, the field of study indicator was also examined to further assess the representation of skilled labour in the defence industrial sector. According to the 2001 census data, those with engineering, mathematics and the physical sciences are well represented in the CDIB sectors compared to the total industry average. In particular, the aerospace, electronics and chemical sectors show above average representation of engineers even when compared to the "Hi-Tech" sector. Those with specializations in mathematics and physical sciences are not as well represented in the CDIB with the exception of the chemical sector (7 %). The "Hi-Tech" sector, in particular the computer industry, had 19% of its labour force trained as mathematicians or physical scientists compared to 2% of the national industrial average (See Table A-12, Annex A).

For the claim that the CDIB may crowd-out talented labour, the evidence is not strong. For instance, in terms of average wages, the CDIB compensates its employees above the industry average, but below the selected "Hi-Tech" industries. As such, the "Hi-Tech" sector is in a position to attract more talent (or crowd-out) than the CDIB. Extending the labour force characteristics analysis to the government sector, the education attainment level of the business sector is lagging behind the government sector especially for those with university education.

The industry average for university educated in 1996 stood at 17% while the government sector had 25%. The percentages for the other education attainment variables were comparable, with the government sector holding a slight advantage (see Table A-12, Annex A).

The defence services sector lagged behind its other federal departments and other levels of government in every category except in the field of study, particularly engineering and applied sciences. In this category defence employed 20% of its labour force compared to the government average of 11%. This was also above the industry average. The government sector also pays above the industry average but below most of the CDIB sectors and the "Hi-Tech" industries. In fact, the government sector is facing considerable competition from the CDIB and the "Hi-Tech" sector for talent than the other way around (Solomon, 1999).

2.2.3 Size Implications

Focusing exclusively on defence R&D and its overall private-public partnership, is there a sizeable defence industrial base to warrant a policy/strategy? For this question, we focus on some of the stylized facts about the Canadian Defence Industrial Base (CDIB). For the purposes of this study the CDIB is defined using the following broad concepts:

1. Canadian industrial sector that is **both** dependent on military production and relevant to the sector. Relevance to sector can be seen as, for example, important suppliers of weapon systems, etc.

2. A firm that is to some extent dependent on defence spending and/or defence exports and that the nation state is dependent upon for self-reliance in the production of defence goods.

3. The sector may operate in a relatively non-competitive market as a result of economies of scale, technology or government policies.

It is likely that the DND S&T strategy may affect a broader segment of the Canadian industrial sector, thus the above definition may constrain the size of the CDIB under consideration. Nevertheless, such constraints are acceptable for the examination of Canadian defence industrial policies and for the design of empirical studies and policy prescriptions. For example, a broader definition may include some civilian companies such as DELL or even Tim Horton's but these companies are neither important suppliers nor dependent on defence spending.

Canada's defence industry, particularly the aerospace and defence electronics sectors is characterized by significant foreign ownership with many companies being subsidiaries of the large US and European aerospace and defence corporations. The shipbuilding sector is now owned by The Irving group of companies, a Canadian privately-owned business. The Irving holdings range from forest operations including pulp, tissue and newsprint mills to Canada's largest oil refinery and Irving Mainway stores. The military vehicle-manufacturing sector is dominated by the GM Diesel plant in Ontario which was recently bought by General Dynamics Land Systems, a subsidiary of the American Defence firm. However, there are still a number of small and medium Canadian-owned enterprises that support the automotive and military vehicles sector.

The Canadian defence electronics industry includes companies that develop, manufacture and repair radio communications equipment and associated products, acoustic and infrared sensors, and computers for navigation and fire control systems. The sector is also involved in signal processors and display units, special-purpose electronic components, and systems engineering and associated software - all for defence related applications. The traditional end-users of these products have been limited to the military, government agencies and commercial airlines.

The strengths of Canada's defence industry lie in small, dual-use systems that serve both civil and military niche markets. For example, Canada is competitive in markets for flight simulation, space robotics, satellite communication sub-systems and components, and various surveillance and detection products (Grover, 1997). Over half of Canada's defence electronics and aerospace industry sales are to civil and export markets. Defence sales are focused on simulation, surveillance, detection, and communications systems and products. Canadian companies do not manufacture large defence and space systems except to meet domestic requirements, and often serve as sub-contractors for large foreign defence and space programs. As discussed in Solomon (1999), the use of an I-O market share matrix revealed that the CDIB exhibits a considerable amount of sub-contracting activity especially in the aerospace, electronic components and specialized services sectors. Thus, inter- and intra-firm investment and trade are important for Canadian companies.

To give yet another contextual view, the CDIB is compared to other countries defence industries. Canadian firms are not among the top defence firms in the world. Since the Stockholm International Peace Research Institute (SIPRI) began compiling and ranking the top 100 defence firms in the 1990s, four Canadian companies made the list and none were ranked in the top 50 during the period 1990-2000. Bombardier, with regional jets and transportation equipment such as rail cars etc. as its main revenue source, is often listed in the top 100. GM's Diesel Division/ General Dynamics Land Systems, which operates from Canada, has increased its international profile by selling its armoured vehicles to NATO allies and the US and was placed as high as 57th in the SIPRI ranking (SIPRI, 2001). Aircraft and computer simulator designer CAE and communication and computing devices manufacturer CDC are the other major Canadian firms on the list. The most recent (2007) SIPRI ranking shows CAE and General Dynamics both ranked around 91st. Despite the lack of a major military equipment supplier, Canada is ranked 13th among military hardware exporting nations and a market share of about 1.3% according to a recent analysis (SIPRI, 2007) (Table 3, Annex A).

Since DND's R&D funding to the business sector is roughly $100 million, it may not be able to attract the bigger players in the CDIB. However, to the extent that the defence S&T strategy implicitly recognizes the need to adapt, anticipate threat and access innovative ideas, the size of the funding or the firm may not be as necessary. In addition, if DND's S&T strategy is embedded within the organization's own procurement or strategic planning guidance such as capability based planning, it may give industry the right signal that R&D expenditures are warranted since they are likely to result in future procurement. Thus the key message is that major CDIB firms may not be at the table s without substantial contracts or future procurement guarantees. The next section elaborates on this key issue.

The final point on the stylized facts about the CDIB is its unique relationship and access to the US military market and the impact of the April 1999 Department of State regulatory changes to the US International Traffic in Arms Regulations (ITAR), which **increased** the number of items requiring export licenses to Canada. Any future defence industrial policy design in Canada has to explicitly consider ways and means to reduce the general level of insecurity in the US that the technological secrets do not find their way into the hands of non-allied third-party (Solomon 2008).

3 S&T Strategies Federal and DND

The most cogent description of the Federal S&T strategy is that innovation is the main ingredient to prosperity, and minimal government intervention, the preferred policy prescription IC, 2007 p37). The main concern of the Defence S&T strategy is not the nation's macro economy but its security environment.[3] And like the Federal S&T strategy, it acknowledges the government's role is rather limited and the best security solution can be found by leveraging the resources and expertise of the non-public sector.

The Federal S&T strategy of less government is articulated in the following five policy directions(IC, 2007 p51-55):

1. Review existing competition laws to ensure that they are encouraging a more innovative economy

2. Encourage international trade and investment through a comprehensive Global Commerce Strategy and regional and bilateral trade and investment agreements

3. Improve fiscal and institutional strategies to attract new foreign direct investment

4. Identify and develop the Intellectual Property policy "sweet spot" that provides the legal protection necessary to give copyright-based industries the confidence to invest and make full use of leading-edge technologies, while promoting and facilitating the access to the knowledge and information needed for innovation and competitiveness

5. Reduce the tax burden for both corporations and individuals

These five **Laissez-faire** policy directives are at the strategic level but there are also some operational level directives in the Federal S&T strategy that have potential links with the DND's own S&T strategy. These include:

1. Research networks (Centres of Excellence) to build a community of experts from private and public arenas through a competitive national process (IC, 2007 p13, 58).

2. A research and commercialization centre to achieve a critical mass of capacity in areas that support a nation's competitive advantage (IC, 2007 p57)

3. Continuous review and improvements of government R&D support such as the new Strategic Aerospace and Defence Initiative (IC, 2007 p59-60) and,

[3] However, there are positive externalities that will help the Canadian economy.

4. Internal collaboration (Federal S&T community) to develop talent, knowledge transfer, and commercialization among science-based departments and agencies and subsequently with universities and colleges, and the private sector (IC, 2007 p70,72).

    a. Review own intellectual property policies to encourage S&T collaboration and technology transfer through the revitalization of the Assistant Deputy Ministers Committee on S&T.

The **Laissez-faire** approach of the Federal S&T strategy is generally attractive to economists for at least three reasons. First, the government sector is not in a position to know what types of innovations are required or best suited in each industrial sector. Second, providing tax incentives and direct subsidies may be costly because there is a requirement for the monitoring and evaluation of the projects and activities that qualify for the tax incentive. In addition, firms may use the tax advantage for general purpose cost reduction if the monitoring process or the contractual arrangement is inadequate (information asymmetry). Third, the bureaucracy may have its own incentives that may be inconsistent with the social welfare. For example, a bureaucrat may continue a subsidy program in order to protect budgets and jobs even if the program delivers zero social or economic benefit to the sector, region, etc.

The focus and scope of the defence S&T strategy are understandably narrow but most importantly, have a very specific goal of maximizing S&T returns to DND using various administrative and process improvements. Maximizing S&T returns according to the strategy is "quantified" by identifying eight outcomes that will benefit the CF/DND (DND, 2006 p13, 15). These include, among others, a robust Command and Control structure, interoperability, agility and Operational superiority through situational awareness of both the physical and social environment.

These outcomes are to be achieved through enabling attributes such as leverage, linkage, balance, agility, innovation and excellence (DND, 2006 p13, 15). Of these, the first two, leverage and linkage explicitly incorporate the notion of collaboration between private and public as well as between government agencies and foreign equivalents. This is the main area where there is a strong association with the Federal strategy. The defence S&T strategy also sets specific milestones for establishing process models for strategic partnerships as well as enablers (such as intellectual property procurement process harmonization).

The above description is a highly condensed version of both the Federal and defence S&T strategies. There are some commonalities that will allow synergies to be exploited. In addition, the promotion of innovation nation wide (Federal strategy) and the optimization of scarce defence S&T resources (defence strategy) are not mutually exclusive. However, these policies were announced about a year ago and we lack sufficient data to conduct an empirically based evaluation. Thus, we utilize a lessons learned approach from previous Government of Canada industrial polices as well as by reviewing existing literature on R&D policies from the US.

3.1 Economics Literature on IRB Policy

Industry Canada is the main Government of Canada agency with the mandate to support the development of technological capabilities, fostering scientific research and for setting the conditions for an effective marketplace. Specific to S&T and defence, the Industrial and Regional Benefits (IRB) policy is one of their main and most comparable policies to the defence S&T strategy. Note that as discussed earlier the federal S&T strategy is focusing more on the Strategic Aerospace and Defence Initiative. This initiative essentially subsidizes defence R&D spending with some accountability and monitoring provisions. There has been a similar US policy with the same flavour and this is discussed later to provide a lesson learned perspective. In this section we will focus solely on the IRB policy.

The IRB policy primarily uses federal procurement (mostly defence) as a tool to promote industrial and regional development objectives. It is a policy that grew in an environment of declining defence budget and domestic demand and to counter an alleged array of policy instruments used by other nations with whom Canada competes. While the earlier versions of the policy concentrated on offsetting the loss of jobs or other economic benefits to Canada as a result of the external procurement of major defence equipment (Dobell,1981), subsequent adjustments to the policy zeroed in on technological transfer and joint foreign-domestic production. This latter policy development is similar to what is expected in the defence S&T strategy of innovation and linkage.

Such policies are politically attractive because some of the benefits such as jobs (at least for the short-term), foreign investment and regional development programs are realized quickly. Although there are some potential benefits from offsets (particularly technological transfers and development of competitive industries), economically, as will be discussed, such programs may result in higher premiums and marginal benefits. Furthermore, it has been argued that regional distribution of offsets tends to be an inefficient allocation of funds and resources, as well as a hindrance to international competitiveness of Canadian industry (Neilson, 1985; Treddenick, 1984).

Formal evaluation of IRB and its predecessor programs were never uniform and there were no specific methodology employed to analyze the commitments, such as basic cost-benefit analysis. For example, an evaluation of the CF-18 purchase in early 1980s (Gray, 1980) relied heavily on subjective considerations and failed to answer basic questions such as what are the additional costs for administering offsets? Without such information one cannot make optimal choice between complete offshore procurement and domestic purchase. Even if the decision to purchase from abroad is somehow decided, we still want to know the cost of the industrial benefit (Solomon, 1999).

A 1997 study jointly sponsored by DND and Industry Canada utilized a combination of empirical study (using Input-Output models to assess policy impact on industrial sectors) and interview and focus group information from the relevant groups and stakeholders to formulate its findings (Hickling, 1997). The empirical portion of the study found that the IRB policy had an impact, albeit modest, on Canadian industries and marginal benefits in regions outside the dominant Quebec-Ontario region (Alberta and the Prairies). However, the study was not in depth enough to tease out nuances, such as, did the offset policy help expand industrial capability or were defence/aerospace capability created in new regions and sectors?

The Hickling (1997) study also uncovered some insights on the design of industrial policies. First, policies should be flexible enough to adapt to changes in the contextual environment. For example, the WTO policies on subsidies restrict most forms of government subsidies and support. In addition, declining defence budgets at home and abroad reduced the utility of the policy.

Second, government policies require senior level guidance and vision or long-term strategic thought. Without it, monitoring of the results of the policy is poor and feedback of the results into the decision-making process, non-existent. Perhaps related to the lack of senior leadership, the Hickling (1997) study also found that evaluations of IRB policy were perfunctory, and legally binding contracts were not enforced (such as penalties on unfulfilled IRB commitments). Third, wording of strategies should not be vague, since this may allow companies to include activities that supported company business instead of sectoral strategies that would have created incremental benefits.

A recent workshop on IRB and Defence Industrial Base in general, held in National Defence Headquarters, discussed another facet of the policy that may explain some of the Hickling (1997) findings. Specifically, the lack of senior leadership and support is due to the fact that the Canadian government policy is not to have a policy. In essence, enhancing international competitiveness may be ill-advised considering the small domestic defence market and the special defence industrial relationship with the largest military market, the US[4].

In general, the lessons from the IRB policy can be summarized as follows:

1. The primary objective of procurement is to acquire the good with the best value for money and that secondary objectives such as industrial benefits should be pursued only after identifying the incremental costs and benefits of achieving the additional goal (Nielsen, 1985). At the moment, neither the Federal nor the Defence S&T strategy have discussed the need to carefully weigh the costs of the program to the marginal benefits. The defence S&T strategy has measurable goals but these tend to be qualitative and thus limit a true cost-benefit analysis.

2. As much as possible policies should avoid mutually exclusive objectives, such as regional development (in a depressed region) and industrial competitiveness (which benefits from clustering than regional dispersion). At the moment, the objectives of the defence S&T strategy are complementary but the temptation to use policy instruments to accomplish multiple objectives is an ever-present one in governments.

3. Government agencies have differing mandates which, at times, may resemble vested interests. In such situations, i.e. S&T collaboration between various science oriented departments, a policy that elicits maximum cooperation is gain-sharing as an incentive to cooperate. For example, various departments can be persuaded to co-operate if they are allowed to keep any significant savings from the collaboration.

[4] Comments attributed to Materiel Group representatives (October, 2007). The Defence Production Sharing Arrangement (DPSA) with the US allows Canadian defence firms special access to the lucrative US defence market.

3.2 Empirical Lessons from IRB

Solomon (2008) conducted an empirical investigation of IRB policies by using I-O simulations, and concluded that the majority (85%) of the benefits of IRBs were spread among ten industries. The regional distribution was equally concentrated with the traditional manufacturing base of Ontario and Quebec accounting for more than three quarters of the benefits. Sadly, the Atlantic and Prairie provinces, IRB's regional focus, received only marginal amounts.

Another finding of the empirical study confirmed the consolidation of the aerospace sector in Quebec and Ontario. Although this may be a natural phenomenon of the global airline industry, the IRB policy may have played some role. This is, unfortunately, counter intuitive since it may hinder companies from capturing the synergistic benefits of a clustering approach. In other words, established regional clusters may be hurt by movement of work to other regions, making the sector as a whole less competitive (Solomon, 2008).

The empirical evidence illustrated the unintended consequences of industrial policies, especially if they have multiple goals that may be mutually exclusive. Each region and industrial sector has an advantage that it can exploit and there are competing policy tools that can provide benefits suitable to some regions or sectors. From this perspective, the IRB's stated goal of "maximizing benefits flowing to a region" facing "particularly difficult economic circumstances" may be a non-starter if the necessary tax base or infrastructure is not in place to exploit the benefits flowing from a large procurement.

Solomon (2008) also attempted to quantify the true cost of IRB policies using the DND inflation rates as a means of decomposing various cost drivers of Major Crown Projects (MCP). A comparison of various defence programs with and without IRB stipulations shows that IRB-based project tends to be inflationary. The inflation differential is used as a proxy measure of the premium imposed by IRB requirements. Thus a 1% differential between the prices of the IRB based project and all other similar non-IRB projects implies a cost of about $10 Million on $1B procurement. This differential excludes common costs to both projects with and without IRBs such as exchange rates, price inflation of foreign labour and parts, domestic inflation on labour and parts, and policy variables (such as special administrative costs on defence procurement excluding IRB).

4 The Economics of R&D and Policy Design

In this section, we review the existing literature on R&D as it pertains to defence. In addition to conducting their own R&D, defence departments can directly contract R&D or subsidize independent R&D. In the US, the Department of Defense (DoD) is also known to sponsor design competition. This latter method has not been used in Canada in the past since the CDIB does not have the capacity to design and build platforms.

The US DoD has conducted both direct R&D contracting and design competition on a number of projects. While this seems redundant, there is a reasonable explanation especially from an economics perspective. The problem for defence departments is their lack of knowledge of firms' marginal product or level of effort. Stating the problem more formally, the principal (government department) cannot directly observe the level of effort of the agents (firms, contractors) without incurring considerable monitoring costs. In such situations, rewards based on relative merit are optimal to individual output.

Similarly, government departments are at a disadvantage when multiple firms with heterogeneous skill sets are involved (the principal cannot monitor the relative ability or productivity of the agents). Economic theory shows that it is optimal behaviour for firms to invest in acquiring, and for departments to rely on, signals of quality (ability). As such, design competition may be seen as a signalling mechanism, where the signal of a firm's ability that the department relies on, is the score on the technical proposal.

The US experience with design competition has been evaluated by a few economists, including Lichtenberg (1988) who used econometric methods to show that for every $1 in government sales a firm invests $0.09 in private R&D. The econometric study also showed that the R&D investment level for non-government revenue was substantially less (a $0.017 increase for every $1 in non-government revenue). Lichtenberg (1988) also showed that competitive procurement induces increases in private R&D since the prospect of substantial future contracts awarded to the winner of the design competition is a very strong incentive.

While the design competition strategy discussed above increases the returns of a firm's R&D investment, DoD also provides a subsidy program that effectively reduces the marginal cost of conducting R&D. The subsidy strategy can be summarized symbolically as:

$$S = \Theta \min(C_{rd}, G_s) \tag{1}$$

Note that subsidy level S is a function of Θ, which is the share of defence sales to total sales and the minimum of total R&D costs incurred (C_{rd}) and ceiling (G_s) on allowable costs to recover from the defence department.

At the margin, the rate of subsidy is equal to

$$\Theta \frac{dG_s}{dC_{rd}} \tag{2}$$

If the ceiling G_s is a negotiated amount between the firm and DND prior to investment, then the above derivative can be set to zero. This implies that the subsidy has no effect on the marginal investment costs as it only reduces total costs. Economists propose that there is actually an impact on the marginal rate and attempt to test this using past data on R&D expenditures. Note that the firm's announced R&D commitment is not observed, thus to empirically estimate this unobserved value economists use expectation theory, which forecasts the unobserved value by a distributed lag function of actual expenditures with geometrically declining lag coefficients.

Estimates based on the above method show that the marginal rate of subsidy is about 40%. The rationale for providing both subsidy and prizes for innovation is that the government costs may be lower with this combined strategy as opposed to with prize competition. In addition, by providing subsidy, the government shares with the contractor the risk of investment. Having a ceiling gives the allure of controlling costs and a say in the transfer of knowledge and technology (Lichtenberg, 1991). Having guaranteed government contract has some obvious drawbacks such as allowing firms to transfer costs from commercial to government operations. In addition, empirical studies conducted thus far do not support the hypothesis that defence R&D stimulates civilian R&D down the road.

4.1 Impact of Defence R &D

Next we look at the theoretical and empirical evidence of the impact of defence R&D and civilian R&D on productivity growth. Given Canadian pre-occupation with productivity improvement and the overall federal S&T strategy of investing in R&D for the purposes of improving standard of living, the impact of R&D on productivity is an important factor to assess. Although there is no universally approved definition of productivity and standard of living, there are some quantitatively appealing descriptions that are often used in the economics literature. Thus, GDP per capita is an indicator that is often used to measure the standard of living while productivity is measured by the value of output (GDP) produced per hour worked.

Even this generic definition is not without its problems. For instance, the GDP per hours worked is a good proxy of labour productivity but production involves a combination of labour and capital. A better measure is one that tries to capture the efficiency with which inputs of capital as well as labour are used. This more complete measure is known as multi-factor productivity; however, it is very difficult to measure compared to labour productivity as it is much easier to add up the number of hours worked than to value the capital stock which is a sum of heterogeneous products.

The relationship between standard of living and productivity (from here on measured as GDP per hours worked) can be approximated by the following identity:

$$\frac{GDP}{POP} = \frac{GDP}{hrs} . \frac{hrs}{Emp} . \frac{Emp}{POP} \qquad (3)$$

An improvement of a nation's standard of living (GDP/POP) may be due to an increase in labour productivity (GDP/hrs), an increase in the work effort (hrs/emp) - the number of hours worked per person or the employment rate of the population (Emp/POP). It is clear that there is a natural limit to increasing the later two factors. There are only 24 hours a day and we cannot expect people to work without rest. Similarly, there are demographic limitations on the available stock of workers (proportion of the population that is 15 years or older). Given these limitations productivity improvement through various innovations (read R&D) is the only avenue for increasing standard of living.

Despite some wide differences on the estimate of R&D effects on productivity, the consensus is that there is a positive link between R&D and productivity. However, shortcomings of the available data and the difficulties associated with existing econometric methods make it difficult to reduce the uncertainty surrounding the size of the contribution that R&D makes. However, firms are profit maximizers and their continued undertaking of R&D projects indicates that the returns from their R&D investment are at least as profitable as alternative use of corporate funds.

Lichtenberg and Siegel (1991) conducted a similar productivity-R&D link study with a particular emphasis on defence. Their study concluded that the return from defence R&D is not statistically different from zero, while the return from civilian R&D was positive and significant. This disappointing result may be due to the difficulty associated with collecting reliable defence R&D data. In fact, the authors used government R&D expenditures as a proxy. In addition, it should be noted that a large percentage of government R&D is devoted to the production of intangible goods such as national defence and health, whose value is often haphazardly imputed in national accounts data (Lichtenberg and Siegel, 1991).

4.2 Economics of Partnerships

The defence S&T strategy is rather vague on how it is leveraging the capacities that exist in the private sector, academia and allied nations. Focusing on the industry-defence relationship for simplicity, we can identify Public-Private Partnership (PPP) as one way for DND to achieve the desired outcome. According to the Canadian Council of Public-Private Partnership, PPP is defined as

> *"A cooperative venture between the public and private sectors, built on the expertise of each partner, that best meets clearly defined public needs through the appropriate allocation of resources, risks and rewards"*

Certainly this definition is consistent with the objectives of the defence S&T strategy of delivering timely and valuable S&T assets and services by developing collaboration between the various S&T partners including industry or the private sector. There have been practical examples of a PPP between the S&T community in DND and the private sector. DRDC Suffield obtained considerable industry expertise while Computing Devices Canada acquired intellectual knowledge enabling it to commercialize defence technologies and pursue market opportunities. Yet, for every success story such as DRDC-Suffield and CDC, there is a spectacular failure such as the US Air Force and Boeing. Boeing and the US Air Force collaborated on a purchase/lease arrangement for the Air Refuelling Tanker project. Due to lack of accountability checks and balances, corruption led to a $500 million penalty for Boeing and a jail term for an Air Force official (Bjerga, 2004)

There are a number of reasons why PPP may not deliver the desired outcome. It may be the conflicting objectives of the partners; private businesses maximize profit while the public sector pursues value for money. This in itself should not be a hindrance, however. The two objectives can be aliened with a clearly designed contract that guarantees an appropriate compensation for risks taken and enforceable penalties for poor quality, delays and cost overruns.

But designing an optimal contract is not cheap; there are transaction costs. These are costs associated with collecting information, writing and negotiating contracts and finally monitoring and enforcing these same contracts. The economics of transaction costs (TCE) identifies four problems that negatively impact partnerships (Hartley and Singleton, 1990).

First, firms can lock in their public partner by investing in specific assets and facilities that act as barriers to entry. Such investments in specific assets can make it prohibitively costly for other companies to compete in subsequent re-bidding of the contract. These assets need not be physical, bureaucratic know how is also used as a way to hinder other competitors.

Second, if the public partner is looking for technological superiority (defence systems to counter potential enemy) this may lead to a more complex contractual arrangements increasing transaction costs.

Third, the higher the uncertainties associated with the technology or the contract (high probability that the contract will be cancelled), the less the contractor will invest in capital equipment, the higher the contingencies and the more labour-intensive the production. All of these leading to higher costs.

Fourth, the more frequent the relationship between the partners the lower the transaction costs since the trust level reduces the need for more protective (costly) forms of governance. In addition, the private partner becomes the most efficient provider.

4.3 Transaction Cost and S&T

The lessons from TCE literature can be applied to any future partnerships between the S&T community in DND and the private sector. However, there are some S&T specific assets and arrangements such as intellectual property rights, technology transfers and spin-on/offs that require proper definition before we proceed to the application of TCE.

Winebrake (1992: 54) defines technology transfer as a process by which knowledge (information) developed in one area (organization, etc) is utilized in another area. Within the defence arena, technological transfers are feasible if the private partner controls its share of the benefits and the defence department is willing to transfer the knowledge. TCE implications for technology transfers are fairly straightforward. First, the public partner (DND) must establish the appropriate legal framework and the means to transfer or share the rights with a private or any other agent. Second, in order that neither party takes advantage, a mechanism that enhances incentives must be established. Such a mechanism is required to make the technology transfer successful.

Economics and business transactions are about incentives. No firm is willing to incur sunk costs without some assurance or expectation that the civil application it is developing from a defence technology is going to generate profits or is not going to be expropriated. Thus the contract or the Intellectual Property Right (IPR) has to be well-defined and provide some guarantee on the sharing of the technology commercialization.

The other unique arrangement in defence S&T partnership comes from spin-on/offs. This is another case of a technology transfer where the knowledge (information, etc) is generated in the defence sphere and is transferred in the civilian sphere. When the knowledge is generated in the civilian sector and transferred to the military it is called a spin-on. This is not as predominant in the literature but it will remain susceptible to weakly designed IPR or contracts. Again, the lessons from TCE show that incentives and flexible IPR regimes will provide the right environment for a joint venture between defence S&T laboratories and the private firms. That is, DND emphasizes R&D cooperation and induces private partnership through a supportive licensing agreement. The licensing agreement, in turn, is seen as a signal to private firms that substantial future expenses are warranted to market and commercialize defence technology.

4.4 IPR and Contract Design

From TCE we have learned that an effective partnership requires well-specified contracts and flexible IPR. However, to design such optimal contracts is not as easy as stated. In subsequent paragraphs, we examine lessons learned from previous contracts in the Europe and the US. For instance, a US program known as the Technology Reinvestment Program (TRP) was able to transfer about 33% of defence technology to the civilian sector while 58% were in the process of being introduced. The US government was able to access of some of industry's best ideas while industry was allowed to retain rights to the intellectual property generated during the TRP.

TRP was successful because the IPR and associated contracts were improved upon after a number of trials and the realization by the US government that strong IPR were counter productive. According to Bellais (2000), strong IPR either increases the cost of the license and initial investment, reducing future profits, or reduces the opportunity to exploit the given pieces of knowledge outside the perimeter of the specific license (David, 2001). A tightly specified contract increases the transaction costs to the public partner (writing, information gathering) while the transaction costs after the signing of the contract increases transaction costs associated with the monitoring and, reporting on both the private and public partner.

Anton and Yao (2004) describe other drawbacks of a strong IPR such as restricting access of knowledge, which leads to inhibition of innovation or exclusion of potential civilian partners for alternative commercialization. If DND imposes exclusive rights, this effectively restricts the use of knowledge and its exploitation by those who may have benefited from it, had it been free. It is understandable that making information public may be a difficult decision for defence and its public partners. After all, in defence the goal is technological superiority and it can be achieved when a potential enemy is denied access to technical information to replicate it. But not all information is strategically valuable, thus making information public engenders rights and also the means to sanction misuse.

5 Summary and Conclusions

The purpose of this study was to evaluate the Defence S&T strategy from an economics perspective. The study looked at previous Government of Canada policies as well as stylized facts about S&T expenditures and trends to gauge the relative size within the Canadian economy. Some transaction cost economics aspects of a potential public-private partnership were also explored to provide some policy guidance.

If attracting private sector partners is one of the main goals of the S&T strategy, certainly the amount of money at play is of interest. The stylized facts section of this paper outlined some basic statistics on the total S&T expenditures in Canada. In general Canada spends about 2% of its income (GDP) or about $25 B in R&D and related scientific activity (data collection, application, etc). Compared to the G7 nations, Canada's spending is ranked 5th ahead of Italy and the UK. The business sector R&D spending of about 1% of GDP is considerably below most G7 countries and selected developed countries such as Sweden and Australia. Since firms are profit maximizers, the lack of innovation may point to an unfavourable fiscal or legal environment.

Defence S&T expenditures totalled $249M in 2007 of which about half was farmed out to the private sector. In terms of total defence expenditures, this level of expenditure is roughly 1.5%. DND's R&D funding to the business sector is roughly $100 million or 4.5% of DND's capital budget. Questions about the adequacy of the spending level tend to be answered through comparisons with similar nations or through opportunity costs considerations. Either method reveals that R&D, and specifically defence R&D, is not a priority item in Canada. In addition, this level of investment may not be able to attract the bigger players in the CDIB.

Since the S&T strategy is trying to optimize the available S&T asset and budget, one should not expect an increase in future budgets as a given. Canadian governments have historically been unprepared to spend significant amounts of money on defence. There are a variety of reasons for this but the most significant reason is that the Canadian public does not see a need for increased defence expenditures, particularly when that expenditure is placed within the context of choosing between defence and health care, education or other social programmes and perceived level of threat. Regardless of the correctness of this choice, defence funding in Canada is always based on what the government believes it can afford and not what a government defence policy might imply (Stone and Solomon, 2005).

The general impact of R&D spending, whether civil or defence, on the macro economy is also assessed in this study. The consensus is that civilian R&D spending does improve a nation's productivity and by extension, its standard of living. The same cannot be said for defence, however. The fact that the benefits of defence R&D are intangibles (the betterment of national defence and security), imply quantifiable data are hard to find. In addition, recent studies seem to point out that defence R&D may crowd out private investment in R&D. The most important result to draw from these studies is that a Canadian specific assessment is absent from the literature and such Canada-specific studies are warranted to make an informed policy choice.

Thus future studies should look at the macro and micro economic implications of defence R&D and the partnership types that elicit the optimal R&D participation from non-governmental entities. To the extent that defence R&D is about quality as opposed to quantity in capabilities investment, an empirical study on the effect of previous R&D investment on the quality and capability of the CF assets should be explored. There are also data quality issues that need to be addressed before embarking on a detailed empirical assessment.

Going forward with the S&T strategy, there are some general recommendations on how to design an optimal contract and intellectual property rights regime. Writing the optimal contract is difficult. One cannot anticipate all unknown and unknowable future events. In addition, defence is unique for its requirement for contracts covering a long period of time or a technological superiority that demands the contractor to commit to funding costly and highly specific investments. In addition, the strategic environment is highly uncertain. In an adversarial environment of military conflict secrecy may be a key feature. However, knowledge is a unique public good that benefits from cumulative effect and the return on investment may be reduced without the interactive environment.

The key to a good IPR is that it is not too strong to deter cooperation or constrain incentives and not too weak to leave the public with no benefit from its investment in S&T. It should allow both parties to mange risks and secure their respective share of future returns. Foray (2001) and Anton and Yao (2004) provide the following recommendations for establishing an IPR and contract framework that will lead to an effective partnership between the public and private sector.

1. Free flowing information about the technology (knowledge) to transfer or to spin off

2. IRP flexibility by determining the optimal perimeter for patents

3. Reduce transaction costs associated with uncertainties (contracts between the public and private partners should be clear and transparent)

4. Establish mechanisms to facilitate the development of civilian applications.

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Annex A Supplimentary Data

Annex- A Table A- 11 Education Attainment and Field of Study by Industry Census 2001

Education Level and Field of Study	All Industries	Other Metal Fabricating Industries	Aircraft and Parts Industry	Railroad Rolling Industry	Ship Building Industry	Communication and Other Electronics	Other Chemical Products Industry
Percentage of Total Labour Force							
Less than high school graduation certificate	21%	26%	10%	19%	22%	10%	20%
High school graduation certificate only	15%	18%	13%	11%	10%	12%	18%
Some postsecondary education	12%	10%	8%	9%	8%	10%	12%
Trades certificate or diploma	13%	22%	22%	29%	41%	9%	12%
College certificate or diploma	18%	15%	25%	18%	15%	23%	19%
University certificate or diploma below bachelor's degree	3%	1%	3%	2%	1%	3%	2%
University degree	19%	7%	18%	11%	4%	32%	17%
Bachelor's degree	13%	5%	12%	8%	3%	22%	13%
University certificate above bachelor's degree	2%	1%	2%	0%	1%	2%	1%
Master's degree	3%	1%	3%	2%	0%	7%	2%
Earned doctorate	1%	0%	0%	0%	0%	1%	1%
Total labour force by major field of study							
No postsecondary qualifications	47%	55%	31%	40%	39%	32%	50%
Educational, recreational and counselling services	5%	1%	1%	0%	0%	1%	1%
Fine and applied arts	3%	1%	1%	1%	2%	2%	2%
Humanities and related fields	3%	1%	2%	1%	0%	2%	2%
Social sciences and related fields	6%	1%	2%	2%	1%	3%	2%
Commerce, management and business administration	12%	8%	10%	7%	4%	12%	12%
Agricultural, biological, nutritional, and food sciences	2%	1%	1%	1%	1%	1%	2%
Engineering and applied sciences	3%	3%	11%	6%	2%	18%	5%
Applied science technologies and trades	12%	27%	39%	40%	49%	21%	17%
Health professions and related technologies	6%	1%	1%	1%	1%	1%	1%
Mathematics, computer and physical sciences	2%	1%	2%	1%	0%	6%	7%
No specialization	0%	0%	0%	0%	0%	0%	0%
Average employment income in the reference year $	**$ 32,123**	**$ 36,771**	**$ 47,297**	**$ 44,405**	**$ 31,825**	**$ 47,128**	**$ 44,028**

Source: Statistics Canada Census 2001

Annex- A Table A- 12 Education Attainment and Field of Study by Industry and Government Sector Census 2001

Education Level and Field of Study	Air Transport Industries	Computer Related Services	Defence	Other Federal	Province	Local	International and Other Gov't
Percentage of Total Labour Force							
Less than high school graduation certificate	9%	3%	13%	5%	5%	13%	6%
High school graduation certificate only	14%	5%	19%	12%	12%	13%	11%
Some postsecondary education	15%	11%	15%	13%	9%	13%	8%
Trades certificate or diploma	15%	6%	17%	7%	8%	13%	6%
College certificate or diploma	29%	26%	18%	23%	25%	27%	19%
University certificate or diploma below bachelor's degree	3%	4%	2%	4%	5%	4%	5%
University degree	16%	46%	16%	37%	36%	17%	47%
Bachelor's degree	13%	32%	12%	24%	24%	13%	23%
University certificate above bachelor's degree	1%	3%	1%	3%	3%	1%	7%
Master's degree	1%	9%	3%	8%	8%	3%	14%
Earned doctorate	0%	1%	0%	2%	1%	0%	2%
Total labour force by major field of study							
No postsecondary qualifications	37%	19%	47%	30%	27%	39%	24%
Educational, recreational and counselling services	7%	2%	2%	4%	4%	4%	4%
Fine and applied arts	2%	2%	1%	1%	1%	1%	1%
Humanities and related fields	5%	5%	3%	6%	5%	3%	11%
Social sciences and related fields	6%	6%	7%	16%	21%	18%	16%
Commerce, management and business administration	11%	14%	8%	22%	22%	15%	26%
Agricultural, biological, nutritional, and food sciences	1%	1%	2%	4%	3%	2%	2%
Engineering and applied sciences	3%	10%	4%	3%	3%	3%	4%
Applied science technologies and trades	25%	21%	21%	8%	8%	12%	6%
Health professions and related technologies	2%	1%	2%	2%	2%	2%	1%
Mathematics, computer and physical sciences	2%	19%	2%	4%	3%	1%	3%
No specialization	0%	0%	0%	0%	0%	0%	0%
Average employment income in the reference year $	**$ 44,170**	**$ 49,784**	**$ 40,704**	**$ 43,895**	**$ 41,524**	**$ 36,152**	**$ 39,471**

Source: Statistics Canada Census 2001

Annex- A Table A- 13 Companies with the Highest R&D Intensity

Rank 06	Name	2006 RD Expenditures	Revenue	RD Intensity (RD/Revenue	Industry
42	Neurochem	$58,624	$3,197	1,833.70	Pharmaceuticals/biotechnology
93	ProMetic	$16,098	$2,647	608.2	Pharmaceuticals/biotechnology
80	Isotechnika	$22,151	$4,106	539.5	Pharmaceuticals/biotechnology
84	Resin	$21,815	$4,352	501.3	Chemicals
91	Azure	$17,600	$5,771	305	Transportation
56	Cardiome	$43,438	$20,668	210.2	Pharmaceuticals/biotechnology

Source: Research Infosource Inc. 2006

Annex- A Table A-14 Top Military Goods and Services Exporters 2000-2007

Rank 2000-2007	Supplier	2000	2001	2002	2003	2004	2005	2006	2007	2000-2007
1	USA	$ 7,505	$ 5,801	$ 4,984	$ 5,581	$ 6,616	$ 7,026	$ 7,821	$ 7,454	$ 52,789
2	Russia	$ 4,190	$ 5,631	$ 5,458	$ 5,355	$ 6,400	$ 5,576	$ 6,463	$ 4,588	$ 43,661
3	Germany (FRG)	$ 1,622	$ 825	$ 910	$ 1,707	$ 1,017	$ 1,879	$ 2,891	$ 3,395	$ 14,246
4	France	$ 1,033	$ 1,235	$ 1,342	$ 1,313	$ 2,267	$ 1,688	$ 1,586	$ 2,690	$ 13,154
5	UK	$ 1,356	$ 1,116	$ 772	$ 624	$ 1,143	$ 871	$ 978	$ 1,151	$ 8,010
6	Netherlands	$ 259	$ 192	$ 243	$ 342	$ 218	$ 611	$ 1,575	$ 1,355	$ 4,794
7	Sweden	$ 308	$ 850	$ 125	$ 468	$ 287	$ 536	$ 437	$ 413	$ 3,424
8	Italy	$ 192	$ 224	$ 408	$ 311	$ 210	$ 818	$ 694	$ 562	$ 3,420
9	China	$ 228	$ 507	$ 561	$ 580	$ 288	$ 271	$ 562	$ 355	$ 3,353
10	Ukraine	$ 280	$ 661	$ 244	$ 397	$ 354	$ 308	$ 563	$ 109	$ 2,917
11	Israel	$ 316	$ 298	$ 365	$ 309	$ 561	$ 280	$ 246	$ 238	$ 2,614
12	Spain	$ 46	$ 7	$ 120	$ 158	$ 56	$ 133	$ 825	$ 529	$ 1,873
13	**Canada**	**$ 109**	**$ 129**	**$ 182**	**$ 276**	**$ 302**	**$ 206**	**$ 210**	**$ 343**	**$ 1,757**
14	Switzerland	$ 104	$ 102	$ 102	$ 120	$ 217	$ 196	$ 208	$ 211	$ 1,260
15	Belarus	$ 293	$ 299	$ 56	$ 80	$ 50	$ 24	$ 35		$ 838
16	Poland	$ 43	$ 70	$ 43	$ 72	$ 43	$ 17	$ 255	$ 135	$ 678
17	South Korea	$ 8	$ 165		$ 104	$ 20	$ 32	$ 80	$ 214	$ 623
18	Uzbekistan			$ 73	$ 340	$ 170	$ 4			$ 587
19	South Africa	$ 18	$ 29	$ 16	$ 43	$ 71	$ 24	$ 140	$ 80	$ 420
20	Czech Republic	$ 78	$ 87	$ 58	$ 64	$ 1	$ 68	$ 38	$ 13	$ 406

Source: SIPRI Year Book 2007

Annex- A Table A-15 R&D Performance and Funding Profile 2007

Performing Sector						
Funding Sector	**Federal**	**Provincial**	**Business enterprise**	**Higher education**	**Private non-profit organizations**	**Total**
2007 Total sciences	$ Millions					
Total	**2,338**	**299**	**15,773**	**10,433**	**116**	**28,984**
Federal government	2,280	1	330	2,787	38	**5,437**
Provincial governments	5	288	97	1,067	13	**1,482**
Business enterprise	53	10	12,874	881	11	**13,840**
Higher education	.	.	.	4,758	.	**4,758**
Private non-profit organizations	.	.	.	813	36	**849**
Foreign	.	..	2,472	127	18	**2,619**

S&T Expenditures by Industry Types 2003-2007

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List of symbols/abbreviations/acronyms/initialisms

CDIB	Canadian Defence Industrial Base
CIDA	Canadian International Development Agency
CIHR	Canadian Institute for Health Research
CF	Canadian Forces
CFI	Canadian Foundation for Innovation
CORA	Centre for Operational Research and Analysis
DND	Department of National Defence
DoD	Department of Defense (United States)
DRDC	Defence Research & Development Canada
FC	Foreign Parent Company
FY	Fiscal Year
G7	Group of Seven (Industrialized Nations)
GDP	Gross Domestic Product
IC	Industry Canada
IRB	Industrial Regional Benefit (policy)
IPR	Intellectual Property Rights
IT	Information Technology
ITAR	International Traffic in Arms Regulations
MCP	Major Crown Projects
NRC	National Research Council
NSERC	Natural Sciences and Engineering Research Council
OECD	Organization for Economic Cooperation and Development
PPP	Private-Public Partnership
R&D	Research & Development
RSA	Related Scientific Activity
SSHRC	Social Sciences and Humanities Research Council
SIPRI	Stockholm International Peace Research Institute
TCE	Transaction Costs Economics
TRP	Technology Reinvestment Program (United States)
US	United States

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3. TITLE (The complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title.) Defence Science and Technology Strategy:: An Economics Perspective			
4. AUTHORS (last name, followed by initials – ranks, titles, etc. not to be used) Solomon, B			
5. DATE OF PUBLICATION (Month and year of publication of document.) November 2008	6a. NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.) 59		6b. NO. OF REFS (Total cited in document.) 26
7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.) Technical Memorandum			
8. SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the research and development – include address.) Defence R&D Canada 305 Rideau Street Ottawa, Ontario K1A 0K2			
9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.)	9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)		
10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document.) DRDC CORA TM 2008-050	10b. OTHER DOCUMENT NO(s). (Any other numbers which may be assigned this document either by the originator or by the sponsor.)		
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This paper is exploratory in nature and provides a macro-level assessment of the Department of National Defence (DND) Science and Technology (S&T) strategy. The primary tool of assessment is economics since it is the study of scarce resources, which happen to have alternate uses. Specifically, military budgets are at best constant as governments have to contend with other priorities, such as an aging population. In addition, within the S&T domain, defence research and development (R&D) have opportunity costs through the use of scarce scientific personnel and assets that could be used for civilian research.

In addition, the paper examines current Federal S&T strategies as well as previous industrial policies such as the Industrial and Regional Benefits (IRB) program to draw lessons learned. Some transaction cost economics aspects of a potential public-private partnership are also explored to provide some policy guidance.

Cet article, de nature exploratoire, a pour objet d'évaluer dans son ensemble la stratégie du ministère de la Défense nationale (MDN) en matière de science et de technologie (S-T). Le principal instrument d'évaluation en l'occurrence est l'économique, car cette science a pour objet l'étude de la rareté des ressources, et il se trouve que celles-ci peuvent être affectées à différents usages. En particulier, les budgets militaires sont stables dans le meilleur des cas, puisque les autorités publiques doivent répondre à d'autres priorités comme le vieillissement de la population. En outre, dans le domaine de la S-T, la recherche-développement pour la défense implique des coûts d'option, car elle nécessite l'emploi de scientifiques et de ressources matérielles qui sont déjà en quantité limitée et qui seraient autrement affectés à la recherche civile.

L'article examine par ailleurs les stratégies actuelles du gouvernement fédéral en matière de S-T, ainsi que les politiques industrielles antérieures, comme la Politique des retombées industrielles et régionales, afin d'en tirer des enseignements. Enfin, l'auteur étudie le concept du partenariat public-privé sous l'aspect des coûts de transaction pour assurer une orientation stratégique.

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Science and Technology, Research and Development, Transaction Cost Economics, Defence Industrial Base, Industrial and Regional Benefit Program

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