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Defence Research: A Versatile 'Helix' of the National System of Innovation

by/par

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Abstract

This paper argues that science and technology in general and defence research in particular can be powerful elements of the national economic strategy and, by extension, of national security. It then presents evidences that investments in defence research, combined with industrial and academic research, did indeed play a key role in the emergence and maturation of Canada's system of innovation and economic development. The paper uses the qualitative evidences to validate an empirical socio-political model of the innovation process known as the Triple Helix.

Within the context of a continuously transforming security setting, the commitment by the federal government to double its investment in science and technology by 2010, and its objective to stimulate innovation across Canada, there is an opportunity for defence research to become an even more effective contributor to the security and prosperity agenda of the country. On the basis of the Triple Helix model, the paper finally presents specific recommendations to that effect.

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Introduction

"*It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow*."

Robert H. Goddard

In 1996, US Center for Strategic & International Studies stated in a report: "All of the nation's basic challenges, including health, defense, and the global economic competitiveness, ultimately have only one fundamental objective: to enhance the quality of life of the citizenry."[1]

To tackle this limitless challenge of the "pursuit of happiness"[2], governments have only a limited number of tools in their strategic toolbox: Foreign Policy, Economic Policy, Defence Policy and Social Policy[3]. Perhaps to the chagrin of the scientific community, science is not one of the four national policy areas.

Strategic planning theorists argue that science is such a fundamental part of to each policy area that it has to be integral to it (e.g. defence research as an integral part of defence policy). However, they also argue that the government should coordinate these individual elements of scientific policy for coherence and maximum effectiveness.[4]

Based on the premise that science and technology are pervasive in all spheres of the Canadian society, this paper will show how the Triple Helix socio-political model of innovation, recently proposed by Etzkowitz & Leydesdorff, can explain the essential

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[1] Harold Brown and Charles Herzfeld (Chairs), *Global innovation/national competitiveness*, A Report of the Senior Policy Group on National Challenges and the Senior Action Group on R&D Investment Strategy, Washington: CSIS, 1996, p. 1

[2] Preamble of the Constitution of the United States of American, 1789

[3] Macnamara, W.D., Fitz-Gerald, Ann, *A National Security Framework for Canada,* Policy Matters, Vol. 3, no. 10, Montreal: Institute for Research on Public Policy, October 2002, p. 23

features of the Canadian technological development—military and civil—of the period between 1916 and 1996.

With the recent evolution in the global security environment, the commitment by the federal government to double its investment in S&T by 2010, and its objective to stimulate innovation across Canada, there is an opportunity for defence research to play a bigger role in the national system of innovation and to enhance both the security and prosperity of Canadians.

Through the hindsight provided by the Triple Helix model, the paper will also show how defence research can benefit from, and contribute to, the emerging Canadian system of innovation.

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[4] Macnamara, W. Donald, "*Strategic Goals and Directions",* in Law, Cecil E., George R. Lindsay and David M.Grenville (Ed.), "Perspectives in Science and Technology: The Legacy of Omond Solandt", Kingston : Queen's Quarterly, 1994, p. 207

The Socio-Political Economics of Science

Supply & Demand is a simple yet powerful theory to explain what, how and for whom all goods and services are produced by the economy of a nation. In accordance with a Supply and Demand framework, scientific research is just another kind of services that the 'invisible hand' of the free market or the government manages to supply if there is a need or a demand. [5]

Beside the unlimited curiosity of Man to apprehend the world and his general desire for a better life, the most important force driving the demand for scientific research is certainly the fundamental human need for health and security. When his well-being or survival is at stake, Man will mobilize material, financial and intellectual resources, to equip himself against undesirable prospects brought about by diseases and war.

To better explain how 'the invisible hand of innovation' (to paraphrase Adam Smith) works, we also need another macro-level model to elucidate the socio-political interactions between the various actors in the production of S&T and the evolution through time of their respective roles. In this paper, I will use the Triple-Helix Model developed by Leydesdorff and Etzkowitz to describe the relations between government, industry and university in the process of innovation.[6]

The evolution of, and the conflicts between, the various players can be represented by various configurations of the basic Triple-Helix model. Leydesdorff and Etzkowitz have suggested three "snap-shots" of the model as a normative or policy guide for national systems of innovation: [7]

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[5] Blomqvist, Ake, Wonnacott, Paul, Wonnacott, Ronald, "*Economics*", 2nd Canadian Edition, Toronto: McGraw-Hill Ryerson, 1987, p. 55-56

[6] Leydesdorff, Loet, and Erzkowitz, Henry "Triple Helix of Innovation: Introduction", *Science and Public Policy*, Vol. 25, no. 6 (Decembre 1998), p. 358-364

[7] Leydesdorff, Loet and Etzkowitz, Henry, "Le 'Mode 2' et la globalisation des systèmes d'innovation nationaux", *Sociologie et Sociétés*, Vol. XXXII no. 1 (2000), p. 135-156

- In Triple-Helix Mode I (Fig. 1), the *government* plays a dominant role and encircles the *university* and *industry* entities; it would represent relations in a socialist economy like the former USSR.

- In Triple-Helix Mode II (Fig. 2), the spheres of influence of the three players are very distinct and their relations very circumscribed; this applies to *laissez-faire* economy exemplified by the United States.

- In Triple-Helix Mode III (Fig. 3), interactions between the various players overlap and are more organic; this model would better explain the new knowledge-base economy where the roles and the responsibilities of the government, industry and academia are characterized by ephemeral clusters, public-private partnership arrangements and continuously evolving networks.

Possibly the most interesting feature of the Triple-Helix Model (especially the third variant) is its non-linearity and its ability to model chaotic behaviour.[8]

In the next section, I will describe the historical evolution of research in Canada, from 1916 to 1996. For the purpose of the paper, I have divided the period into 3 eras, separated by watershed events in the socio-political landscape of the nation. The first era (1916-1939) covers the period from World War I to the beginning of World War II, the second (1939-1968) from World War II to the beginning of the 'crisis of capitalism', and the third from 1968 to the present.

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[8] Ibid., p. 139

The "Corporatism"[9] Era (1916-1939)

Prior to World War I, Canada was still a developing country with an economy very much tied to natural resources. As would be expected, most of the scientific research in the country was focused on the resource industry. In all cases, the government played a important role: the foundation of the Geological Survey of Canada (1842), the development of a network of experimental farms (1886), the establishment of the Fisheries Research Board (1898) and of the Forest Product Lab (1913)[10]. As to the other spheres of innovation, a 1917 survey showed that Canadian industry as a whole was spending less than $100K/year on R&D and the universities did not have more than two dozens of graduate students[11].

It is during World War I that the Canadian government became interest in industrial research, at the instigation of the British Secretary of State for the Colonies. In June 1916, six cabinet ministers of the Dominion of Canada formed a committee to study how research could prop up the war effort. In November 1916, an Honorary Advisory Committee for Scientific and Industrial Research was formed to advise the Prime Minister. The Committee, later to become known as the National Research Council (NRC), originally consisted of 11 representatives from industry, academia and business. For the first few years, the Committee did little more than survey the problem.[12] Still, Canadian scientists and engineers had got involved in the solutions of novel military challenges (aerial warfare, chemical warfare, automatic weapons) and to problems of industrial manufacturing.[13]

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[9] Langford, Cooper H., Martha W. Langford, R. Douglas Burch, "The 'Well-Stirred Reactor': Evolution of Industry-Government-University Relations in Canada", *Science and Public Policy*, Vol. 24, No. 1 , p. 22

[10] Ibid., p. 22

[11] de la Mothe, John, *Government Science and the Public Interest,* Ottawa: Natural Resources Canada on behalf of the ADM Committee on S&T, 1999, p. 13

[12] Goodspeed, Capt D.J., *A History of the Defence Research Board of Canada,* Ottawa: Queen's Printer, 1958, p. 5-11

[13] de la Mothe, John and Paquet, Gilles, "Circumstantial Evidence: A Note on Science Policy in Canada", *Science and Public Policy*, Vol. 21, no. 4, August 1994, p. 262

After World War I, NRC continued to play a role of scientific advisor to the Cabinet. It also instituted a grant program with a budget of $30K/year, to assist universities in the development of a strong science base. NRC, through a series of associate committees, coordinated up to 120 research programs of national interest[14]. In 1925, NRC began laboratory work of its own, and in 1932, it opened a central lab on Sussex Street in Ottawa. By 1939, under the chairmanship of Maj.-Gen. A.G.L. McNaughton, NRC employed 300 persons working in five areas (Mechanical Engineering, Physics and Engineering, Biology and Agriculture, Chemistry, and Research Information) and a budget of $900K/year. Before the war, McNaughton had initiated projects on the military use of radio, cathode-ray direction finding for naval aircraft, ballistics, chemical warfare and radar. When World War II broke out, McNaughton was dispatched to Europe as General Officer Commanding (GOC) of the 1st Canadian Infantry Division, Dr. C.J. Mackenzie, Dean of the Faculty of Engineering at the University of Saskatchewan, was appointed Chairman of NRC.[15]

The period from 1916 to the beginning of World War II "was a mixed blessing for Canadian science policy".[16] On the one hand, NRC played multiple roles: policy advisor to the Government, leadership of national advisory committees, university granting agency, intramural research. This tended to create tensions.[17] On the other hand, there is ample evidence that a Triple Helix of industry, government and university networks had emerged by 1939. Many successful arrangements have been documented, with the foundation of the Pulp and Paper Research Institute of Canada (PAPRICAN) being arguably the best case in point.[18] Also, the walls between defence, industrial and academic research appeared to be 'porous', and progress was very much the results of the

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[14] Langford, op. cit., p. 22

[15] Goodspeed, op.cit., p. 5-7

[16] De la Mothe and Paquet, op. cit., p. 262

[17] Ibid., p. 262

[18] Langford, op. cit., p. 22

action of strong individuals with credibility in the different spheres of the Triple Helix. It can hence be argued that the period was a good example of a Triple Helix operating in Mode III (Fig. 3).

The Republic of Science[19] Era (1939-1968)

> "*Science is the soul of prosperity of Nations, and the living sources of all progress*."
>
> Louis Pasteur

When World War II broke out, NRC, universities and industry were mobilized to coordinate and direct all of Canada's military research for the duration of the war. Technical officers of the Canadian Armed Services were closely integrated in the research programs.

The autumn of 1940, after the defeat of France, was possibly the watershed moment for military research in Canada. Because of the intense situation in Europe and because the authorities in Great Britain felt the British Islands were in grave danger, they sent off Sir Henry Tizard on a mission to Ottawa and Washington to explore the best methods of integrating military research between the three countries. "From that moment on, no questions of patents rights or of security would interfere with complete Canadian participation in the scientific war effort"[20]. Mackenzie, Chairman of NRC, having obtained agreement that Canada would be treated as a full partner, opened liaison offices in London and Washington and UK and US scientific liaison offices were established in Ottawa.[21]

In addition to NRC, each of the three services stood up its experimental establishments. The Army had a total of six laboratories of its own, in Valcartier, Ottawa and Shilo; the Navy had one in Halifax; and, the Air Force had six in Ottawa, Edmonton and Toronto. In addition, there were two experimental stations operated jointly with the United

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[19] De la Mothe and Paquet, op. cit., p. 264, using the language of the Lamontagne commission.

[20] Ibid., p. 10

[21] Ibid., p. 8-9

Kingdom and the United States: the Joint CA/US War Disease Control Station, Grosse-Isle, Quebec, and the Chemical Warfare Experimental Station, Suffield, Alberta.[22]

By the end of the war, NRC had built 22 laboratories throughout the countries, and had a staff of 2000 employees, most of them employed in the various fields of military research: radar, medical research, aeronautical engineering, chemistry, explosives, ballistics, aerial photography, biological warfare, armament, nutrition, acoustics, atomic energy, etc.[23]

With the war effort, "a conviction grew up that in almost any field of scientific or technical research, Canada could […] match quality, if not quantity, with any other nations. This sense of self-reliance and quiet conviction of capability was one of the most valuable products of the war."[24] The Canadian nation had reached adulthood: it ranked fourth among the world's industrial nations, and "had just discovered its great strength in science, technology and industry."[25]

In 1944, a few weeks after D-Day, government officials, military leaders, scientists were devoting considerable thought to what could be done to ensure that the advances made by Canadian science during the war years would be properly consolidated. Four basic requirements were identified[26]:

- Retention of scientific personnel in Canada;
- Funding of research by the Government;
- Greater coordination between the various branches of Canadian research; and,

[22] Ibid., p. 9

[23] Ibid., p. 8

[24] Wilfrid Eggleston, *Scientists at War,* Oxford University Press, 1950.

[25] Solandt, O.M., "The Defence Research Board's Untimely End: What It Means for Military Science", *Science Forum 47*, October 1975, p. 19-21

[26] Goodspeed, op. cit., p. 14

- Smooth rebalancing between military and peacetime research.[27]

In August 1945, Lt.-Gen. C. Foulkes was appointed Chief of the General Staff. Foulkes thought that in future wars "the scientist had to play a role of equal importance to that played by the soldier, the sailor, or the airman."[28] The destructiveness and flexibility of the anticipated nuclear ballistic missiles[29] would not allow for extended mobilization time. Nations not ready to fight at the moment of attack would ever be able to regain the initiative. Hence, only 'forces-in-being' (manpower, weapons systems and techniques) would provide an adequate defence." Because it took years to develop a scientific invention to the point it could be used in combat, it followed that "research and development would from now on be one of the most fundamental principles of Canada's peacetime defence policy. To all intents and purposes, technological superiority had been elevated to the position of a principle of war."[30]

Foulkes charged Lt.-Col. Wally Goforth, Chief of Staff Duties (Weapons) to prepare a proposal for the reorganization of Canadian defence research. Like his superior, Goforth was also convinced that the military and the scientist had to work together as a team. On one hand, he felt that an entirely civilian defence research agency would not be satisfactory. On the other hand, "military research was too serious a business to be left entirely to the soldiers"[31]. A great Canadian compromise was that defence research

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[27] It is noteworthy that the US President F.D. Roosevelt had similar considerations in mind at the same epoch. On 17 November 1944, he wrote to Vannevar Bush, Director of the US Office of Scientific Research and Development: "There is, however, no reason why the lessons to be found in this experiment [of team-work and cooperation] cannot be profitably employed in times of peace. The information, the techniques, and the research experience developed by the Office of Scientific Research and Development and by the thousands of scientists in the universities and in private industry, should be used in the days of peace ahead for the improvement of the national health, the creation of new enterprises bringing new jobs, and the betterment of the national standard of living." Ref.: Bush, Vannevar, *Report to the President: Science—The Endless Frontier*, Washington: US Government Printing Office, 1945.

[28] Goodspeed, op.cit., p. 17-18

[29] Foulkes was amongst the first to anticipate the development of the ICBM, given the recent advent of the US nuclear bomb and the German V-2 ballistic missile. See: Goodspeed, op. cit., p. 19-20.

[30] Goodspeed, op. cit., p. 20

[31] Goodspeed, op. cit., p. 31

would be established on tri-service basis and the research organization would have the power to initiate and finance projects of its own.

In December 1945, the Cabinet approved an Order-in-Council creating the position of Director-General Defence Research (DGRD) to coordinate the R&D activities of the three services. Dr. O.M. Solandt was selected for the position. DGRD, a civilian but having a rank equivalent to a Chief of Staff (Lt.-Gen.) would also be a member[32] of the Defence Council, and of the Chiefs of Staff Committee. On 28 March 1947, the Defence Research Board (DRB) was legally created a separate employer (i.e. outside the provisions of the *Public Services Act*) by an amendment to the National Defence Act.[33]

In addition to being a performing defence research organization in its own right, the DRB quickly become "a vitally important factor in the Canadian […] scientific l 0 0 12 433.8880371177803 460.5

A significant evidence that defence research can also be a powerful instrument of industrial development, the DRB "is also credited as [having been] Canada's most effective government agency in stimulating industrial research"[36], for having supported the development of what it is now called 'dual-use' technologies. The following examples illustrate DRB's achievements in the civil domain:

- Electronics, snow and soil mechanics at NRC;
- Nutrition at Fisheries Research Board and Department of Agriculture;
- Construction of Supersonic Wind Tunnels and of the Uplands Flight Research Laboratory, to cater to both military and civil requirements of Canadian aviation;
- Titanium production process by the Shawinigan Water and Power Company;
- Development by Canadair of a maritime reconnaissance aircraft, subsequently adapted as the CL-215 water bomber for fighting forest fires;
- Development of light STOL transport aircraft for the Army by DeHavilland, Toronto, subsequently known as the Buffalo and the Twin Otter[37];
- Black Brant sounding rocket by Bristol Aerospace, originally as an ABM missile, still in use today by NASA, 40 years after its original development;
- Alouette 1 in September 1962 when Canada becomes the third nation to put a satellite in space. The ionosphere research satellite, developed and built by DRB, was expected to last a year; it provided providing useful data for seven years[38]; and,
- Infrared aerial remote sensing of floating ice in the Canadian Arctic, to monitor unauthorized passage of foreign vessels through the North-West Passage and to provide information for safe surface navigation[39].

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[36] Cripwell, J.P., "High Tech Street Names in Kanata", Ottawa: Kourier-Standard, 25 January 2002

[37] Pennie, A.M., "Significant Contributions of Canadian Defence Science", in Law, op. cit., p. 77-84

[38] Discovery Channel Canada, "Canada celebrates 35 years in space". [Cited on 12 March 2003] Accessed: <http://www.exn.ca/Stories/1997/09/29/05.asp>.

[39] Canadian Centre for Remote Sensing, "Remote Sensing Then and Now--Early Beginnings 1960-66", NRCan. [Cited 12 March 2003]. Access: <http://www.ccrs.nrcan.gc.ca/ccrs/org/history/history1_e.html>

The DRB organization peaked in the late 1950s. In 1956-57[40], the DRB budget ($69.3M in 1957 dollars) was equivalent to 4.5% of the defence budget which itself represented 6.6% of the GDP. DRB had a total staff of 2600 (630 scientists and engineers) working in 26 fields, spread among 11 establishments, on 190 active projects. In 1958, Goodspeed, perhaps carried away by his enthusiasm, went so far as stating: "Military research [has become] an organic part of [the] nation's life."[41]

The DRB had never been mandated to become the industrial research arm of the government; this actually was NRC's mandate. As Solandt pointed out in 1975: "[DRB's] measure of success was the scientific and technical competence of [the armed] forces. DRB [had] no aspirations to be known as a great scientific institution. Its aspiration was to ensure that the Canadian armed forces were known as the most scientifically alert and best equipped in the world."[42] On can posit that Solandt had come to the conclusion that this objective could only be accomplished through an active role in industrial development.

With the election of the Progressive-Conservative government in 1958, Canadians were assaulted by self-doubts and the post-war period was definitely over. The 1960-1963 Royal Commission on Government Organization (the Glassco Commission) did not affect the DRB as an organization, but subsequent defence budget cuts surely had their detrimental effects. In the early 1970, the government stood up another rounds of government review, known as the Management Review Group. This review would ultimately result in the 1974 dismemberment of the DRB "in a thoughtless act of mayhem committed in the name of administrative tidiness."[43] The "Republic of Management"[44] has been officially proclaimed.

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[40] Solandt left DRB in 1957 to become VP Research, Canadian National Railways. (In Law, op. cit., p. 100)

[41] Goodspeed, op. cit., p. 2

[42] Solandt, O.M., op. cit., p. 19-21

[43] Ibid., p. 19

[44] de la Mothe and Paquet, op. cit. p. 264.

In addition to the DRB, NRC has also expanded considerably after World War II, focusing on industrial research, but also heavily involved in military research through the famous National Aeronautical Establishment.[45] All the evidences seem to indicate that the Canadian system of innovation was working effectively. In many ways, one could say that World War II and the onset of the Cold War had accelerated the Triple Helix effect initiated before 1939. This Triple Helix operated under an "unwritten science policy […] broadly described as development of a strong indigenous capability in pure science and a high standard of science in universities. By the early 1960s, this policy had been successfully implemented"[46]: international status, capable scientists in a wide variety of disciplines, strong science faculties in the universities, labs and facilities.

The first 15 years after the war has been described as "policy by big bucks"[47] where spending money in the name of national prestige was expected to compensate for the absence of an overall plan. The fact that the Privy Council Committee on Scientific and Industrial Research did not meet once in the 1950s is indicative of the lack of policy direction provided by the government during that period. This was truly the golden age of the Republic of Science in Canada.[48]

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[45] The development of NRC has been amply documented in Eggleston, W., *National Research in Canada: The NRC 1916-1966*, Toronto: Clarke Irwin, 1978

[46] Drury, C.M., "How the Federal Government Views Questions of Science and Public Policy", *Science Forum 47*, October 1975, p. 26-30

[47] de la Mothe and Paquet, op. cit., p. 263

[48] Ibid., p. 263

The "Republic of Management" Era (1968-1996)

"*Canada has never had an overall policy for the evolution of science and technology. From time to time we have identified problems in this field and tried to fix them, usually unsuccessfully. This was because it was not generally understood that there is no quick fix: a science and technology capability has to be grown and built over time and shaped to a set of strategic national goals*."

Omond M. Solandt, 25 March 1993

The first tremors of the management era were the creation of the Royal Commission on Government Organization (the Glassco commission) in 1960. In his final report published in 1963, Glassco recommended that a powerful body be set up by Treasury Board to coordinate the national investment in R&D. Mackenzie, Chairman of the NRC since 1939, successfully advocated for a much weaker Science Secretariat of the Privy Council, which was set up in 1964.[49] The 'Republic of Science' had successfully resisted the first assault from the 'Republic of Management'.

In 1966, this Secretariat was replaced by the *Science Council of Canada,* a group of independent advisors who had been tasked to prepare a comprehensive assessment of the requirements, priorities and resources for R&D in Canada. Perhaps as a tribute to his previous achievements in industrial research, the government appointed Omond Solandt, former Chairman of the DRB as the first Chairman of the Science Council.[50]

Three documents dominated discussions on science policy at the time: two from the OECD and one from the US National Academy of Sciences, *Basic Research and National Goals*. With an emphasis on basic research, the documents also focused on the Gross National Expenditure in R&D (GERD) as the measure of effective science policy.

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[49] de la Mothe and Paquet, op. cit., p. 263

[50] Mullin, J., "O. Solandt—The Science Council Days 1966-1972", in Law, op.cit., p. 150

In 1967, the Science Council, reporting to the Prime Minister, launched a series of studies on research, the various scientific disciplines, and on the application of S&T to the economic, social and industrial challenges of Canada.[51]

In its landmark report *Towards a National Science Policy for Canada* published in 1968, the Council made major findings and articulated a series of recommendations. Arguably, these are still relevant today. For example[52]:

- Science policy goals within the framework of broader national goals;
- Importance of mission-oriented (as oppose to curiosity-oriented) research;
- More emphasis on development and innovation;
- More R&D outside of government labs, by universities and the private sector;
- Short-term goal of a GERD/GDP ratio of 2% to be quickly surpassed; etc.

This initial study was but one of a series of studies and public reports on the subject of science policy. Major works included: *A Science Policy for Canada* by the Senate Special Committee on Science Policy (the Lamontagne Committee) in 1971; the 'Gendron Report' mandated by Prime Minister Trudeau in 1971, but which remained classified until 1987; *Task Force on Federal Policies and Programs for Technology Development* (the Wright Report) in 1984, which identified issues already recognized by Gendron twelve years earlier.

In 1971, the Trudeau government created the Ministry of State for Science and Technology (MOSST), to advice the Cabinet on S&T matters, but not to administer funds.[53]

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[51] Ibid., p. 151

[52] Impact Group, *The Roles of the Federal Government in Performing Science & Technology: The Canadian Context and Major Forces*, Ottawa: Council of S&T Advisors, March 1999, Appendix 1, p. 5

[53] Ibid, Appendix 1, Part 1.

From 1971, there were several other initiatives aimed at providing policy direction to the national S&T effort: the creation of the Natural Sciences and Engineering Research Council (1979), the House of Commons Select Committee on Research, Science and Technology (1986), the National Advisory Board on S&T (1987), the National Science and Technology Policy and the Canadian Strategy for Science and Technology (1988), the networks of Centres of Excellence (1990).[54]

In 1994, as part of a comprehensive Program Reviews, the new liberal government launched another review of S&T policy, a process that culminated in the publication of *Science and Technology for the New Century: A Federal Strategy*[55] in March 1996.

The 'Republic of Management' era witnessed the emergence of management tools and techniques such as program planning and budgeting, the PERT and CPM methods, and strategic planning. In the early years, the tools and techniques were not fully mature and the most famous Ascher & Overholt Basic Strategic Planning Model was only published in 1983[56]. Yet, it is safe to say that the basic strategic concepts around which the early science policy had been articulated were fundamentally sound. Indeed, Charles Drury, oftulagy for Scic in 5 same areas covered by the recent government policies of knowledge[58], internal excellence[59] and, decision-making[60].

Manifestly, the government had accepted the argument that science is not one of the core national policies available to shape the nation's strategic environment. [61] It can be argued that it is the pervasiveness of science and technology that has attracted the policy attention of government. Yet, none of the initiatives provided effective coordination and may even have dispersed the already limited effort.[62] Furthermore, there is a general consensus that they all essentially failed to make a difference in the overall state of the economy throughout the entire period: "The Canadian GERD-to-GDP ratio has been oscillating around 1.5% for the last 30 years, except in the 1970s when it dipped below 1.0%."[63] Numerous explanations for the enduring stagnation have been brought forward by academics.[64] A possibly biased collection of reasons gleaned by this author includes:

- Failure to target and choose S&T areas important to Canada;
- Tensions between industry, government agencies and university;
- Control versus autonomy of science;
- Mistrust of the new science policy machinery by the science-based departments and agencies;

[58] Government of Canada, *Achieving Excellence: Investing in People, Knowledge and Opportunity*, Ottawa: Industry Canada, 2002

[59] Government of Canada, *Science and Technology Excellence in the Public Service (STEPS): A Framework for Excellence in Federally Performed Science and Technology*, Ottawa: Industry Canada, August 2001. Access: <http://csta-cest.gc.ca/pdf/STEPS.pdf>

[60] Government of Canada, *A Framework for Science and Technology Advice: Principles and Guidelines for the Effective Use of Science and Technology Advice in Government Decision Making*, Ottawa: Industry Canada, 2000. Access: <http://strategis.ic.gc.ca/pics/te/stadvice_e.pdf>

[61] Macnamara, W. Donald, "*Strategic Goals and Directions",* in Law, op. cit., p. 206-212

[62] de la Mothe and Paquet, op. cit., p. 265

[63] Voyer, Roger, "Thirty Years of Canadian Science Policy: from 1.5 to 1.5", *Science and Public Policy*, Vol. 26, no. 4, p. 277

[64] Impact Group, op. cit., Part 2 – Academic Scan, p. 30-38

- Efforts undermined by the rapid rotation and junior status of MOSST; and,
- Inflation, recession and fiscal crisis for the entire period.

Some have been more brutal in their assessment, pointing instead to sabotage by the 'Republic of Science' against any central coordination[65]. Another author has claimed that the senior bureaucracy responsible for economic development promoted a neo-classical *laissez-faire* strategy.[66] Possibly a more convincing argument could be made that the period starting around 1968-1973 was a period of profound economic and social transition.[67] Langford & al. have identified three such socio-economic phenomena that have caused major perturbations to the smooth operations of the Triple Helix of Canadian innovation.[68]

First, the Canadian branch industries of mainly American multinationals, increasingly numerous, had their own R&D networks with their US parents, and relied less and less their networks with the Canadian government and academia. Second, Canadian universities themselves were too preoccupied by a rapid expansion of the student body. The enrolment went from 34,800 in 1940 and reached 276,300 in 1975. To manage this enormous growth rate, universities had to hire more and more foreign teachers so that by 1973, only 42.3% of all PhDs living in the country has earned their degree in Canada. Although the 'brain gain' was undoubtedly beneficial to the country, these academics had established their preferred networks with foreign universities, not with local industry or government agencies. Finally, NRC who had been the *de facto* science policy coordinator in the early part of the era, was replaced by the Minister of State for Science and Technology (MOSST), a centrally but impotent policy making apparatus. In 1978,

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[65] de la Mothe and Paquet, op. cit., p. 261-268

[66] Voyer, Roger, op. cit., p. 280

[67] Needman, W. Robert, "Understanding the Canadian Economy", Toronto: Wall & Thompson, 1989, p. 90-91

[68] Langford, op. cit. p. 24

NRC finally lost its role as the university-granting agency of the federal government by the creation of the National Science and Engineering Research Council (NSERC).

At the end of the 1960s, a compartmentalization of Canadian science had been realized. Too many links of communications between the three government-industry-university 'helices' had been severed;[69] the Triple Helix of innovation has started to run in Mode II (Fig. 2).

[69] Ibid., p. 21

Analysis

> *"A question that no government has yet successfully answered: how can S&T be mobilized to help create prosperity for all the world's people, without destroying the free play of intellect on which technology depends."*
>
> F. Kenneth Hare, 1994

Macnamara and others have claimed that Canada's status has suffered because of the negligence of the government to articulate a formal statement of National Security Strategy.[70] They have argued that the missing foundation policy has had a detrimental effect on all national policies, including incoherent foreign, defence, economic or social policies, and ineffective science strategy. However, this explanation may be simplistic, as seen in the previous section.

In the absence of an overarching national strategy, the contemporary challenge of the science-based departments and agencies (SBDA) is to find a suitable answer to Hare's question above.

Let's first review some of the basic strategic issues at hand: growth and prosperity, security, and the role of innovation as an enabler for these goals.

Growth and Prosperity

It is a well-known fact that Canada's prosperity depends on foreign trade for over 43% of its Gross Domestic Product[71], the highest of the G7 nations. World-class competitiveness requires world-class innovation:

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[70] Macnamara and Fitz-Gerald, op. cit.

[71] Fry, Earl, "Canada/US Economic Relations: A Window of Opportunity", *Policy Options*, Vol. 24, no. 2, p. 33

> "Canada, with 0.5 percent of the world's population, generates about 4 percent of the world's scientific knowledge. Although this reflects that Canada is a scientifically active country, it also demonstrates that Canada is highly dependent on the rest of the world for much of the scientific knowledge that it needs to maintain its enviable position. On the technology side, Canada imports 65 percent of its new technologies, the highest percentage among the G7 countries."[72]

In order to continue to be able to share the benefits of an expanding global market by producing goods that are competitive, in terms of performance, price and design, Canada has to accelerate the conversion of its resource-based economy to a knowledge-based economy. [73] Indications are that this conversion is actually happening.

Indeed, annual total-factor-productivity gain or 'the dividend of working smarter', which was of 1.9% between 1963-68, actually flattened out to 0% between 1973-1993. From that respect, Canada is no better or no worse than most western economies, all having gone through the same growing pains. Modern economic theory hypothesizes the slowdown is due to a 'techno-economic paradigm shift', the old economy having petered out, while the new one based on information and communications is being implemented by forgoing present productivity growth[74].

Edmonds convincingly makes the point that "too large a dependency on foreign technologies may have serious long-term implications for the maintenance, development and ultimate international competitiveness of the nation."[75] One could argue that the statement applies to both civil and defence technologies: in the global competition, a nation wins if its 'weapons' (cellular phones or cruise missiles) are technologically

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[72] The Prime Minister's Advisory Council on Science and Technology, *Reaching Out—Canada, International Science and Technology, and the Knowledge-based Economy*, Ottawa: Industry Canada, 2000, p. v

[73] Mustard, J. Fraser, "Future Directions in Science and Technology", in Law, op. cit., p. 226

[74] Peter Nicholson, *Competing Successfully in a Global Economy*, in Law, op. cit., p. 196

[75] Edmonds, Martin. "Technology Dependence: The Hidden Side of Defence Research and Development", in Coopey Richard, Matthew Uttley and Graham Spinardi (Editors), *Defence Science & Technology: Adjusting to Change*, Chur, Switzerland: Harwood Academic Publishers, 1993, p. 45-64

superior. It is the knowledge content that provides much of the value-added of high-technology products.

Security

The first justification for spending money on defence research is to meet the needs of the military.[76] US observers also admit that defence R&D activities do have "macro-economic implications."[77] Still others have argued that the reverse is also true and that "technological competitiveness is a key element of national security."[78] One can be justified to conclude that all S&T advances, defence and civil, should be considered as part of the knowledge-base of a nation, on the whole contribution to its security. The Government of Canada has recently acknowledged that defence research can be a key element of a national innovation strategy:

> "Although the United States does not have a formally articulated innovation strategy, it is, by almost all measures, the most innovative country in the world. Key initiatives include funding basic research in universities, ensuring graduate level educational opportunities for qualified students, funding federal government laboratories and (my emphasis) conducting large amounts of defence research"[79]

The needs of the Canadian Forces have been well documented by the Standing Committee On National Defence and Veterans Affairs (SCONVA) of the House of Commons. Furthermore, SCONVA has made the following recommendation: "With technology playing a more important role than ever before in providing the military with the capabilities needed, research and development in the defence field must continue to be encouraged and sustained."[80]

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[76] Coopey, Richard, Matthew Uttley, Graham Spinardi, in Coopey, op. cit., p. 2

[77] Margiotta, Franklin D. and Sanders (Ed.), *Technology, strategy and national security*, National Defense University Press, 1985, p. 106

[78] Buck, David; Hartley, Keith. "The Political Economy of Defence R&D: Burden or Benefit", in Coopey & al., pp. 13-44

[79] Government of Canada, *Achieving Excellence*, op. cit., p. 90

[80] Parlement of Canada, *Facing Our Responsibilities: The State Of Readiness Of The Canadian Forces*, 4th Report of the Standing Committee on National Defence and Veterans Affairs, May 2002, Chap. 11 http://www.parl.gc.ca/infocomdoc/37/1/ndva/studies/reports/ndvarp04/03-cov2-e.htm

The technology investment strategy of the Department of National Defence (DND) to respond to these emerging requirements is well documented.[81] Yet, the continuing challenge for Defence R&D Canada, DND's research arm, is to maximize the return of this investment for the benefit of both the CF and the Canadian people at large.

Source of Prosperity and Security: Innovation

According to modern theory of economics, it is the human capital and its ability to innovate that will be the key production factor of the new economy.[82] As Omond Solandt said a few weeks before his death: "You can import technology, and manufacturing skills to kick-start a new initiative, but it won't take off and keep going until the knowledge and skills become indigenous and there is continuity."[83] To make effective use of all sources of technology, "R&D is only one element of the innovation process. It must be in balance with other controllable inputs and responsive to those that are not controllable".[84] In essence, R&D and other technical activities are an additional source of indigenous innovation. In summary, it is shared knowledge that is the source of innovation and growth.

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[81] *Technology Investment Strategy for the Evolving Global Security Environment*, Ottawa: DRDC, 2002

[82] "Economic Growth—Explaining the Mystery", The Economist, Vol. 322, No. 7740, p. 15-18

[83] Soland, Omond M., "Message to the Symposium", Law, op. cit., p. xiii

[84] Leggat, L. John. "Technological Innovation in Canadian Defence Industry", in Haglund, David G. Haglund (ed.), *Canada's Defence Industrial Base*, Kingston: Ronald P. Frye, 1988, p. 54

"Is There a Map for the Road Ahead?"[85]

In early 2002, the federal government updated it by publishing *Achieving Excellence: Investing in People, Knowledge and Opportunities—Canada's Innovation Strategy*[86]. The document proposes goals and targets in three broad domains: knowledge, skills and innovation environment. To address the knowledge challenge the government has set two targets for 2010: Canada will rank among the top five countries in the world in terms of R&D performance and, the Government of Canada will at least double its current investments in R&D. The latter target is particularly significant for the federal laboratories, which have been hard hit in recent years by a reduction of 14% in real terms between 1994 and 1999.[87]

To achieve these targets, the government has also committed to "renew the Government of Canada's science and technology capacity to respond to emerging public challenges and opportunities"[88]. And for the first time in a long time, the government acknowledges its role in defence research: "Defence R&D Canada not only supports research into new technology for Canada's military, but also develops and adapts technologies that improve the security and safety of Canadians."[89]

As one of the numerous mission-oriented research arms of the federal government, Defence R&D Canada has the subsidiary mandate to optimize the efficiency of the national system of innovation, first for the benefit of the Canadian Forces, but also for maximum impact on the national knowledge base and the national economy? The Triple Helix model does provide some indications for the way ahead.

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[85] With due credit to Antonia Maioni who used the aphorism in recent article on the reform of health care (Policy Options, Vol. 24, no. 02, February 2003).

[86] Government of Canada, *Achieving Excellence*, op. cit.

[87] The Prime Minister's Advisory Council on Science and Technology, *Reaching Out*, op. cit., p. 20

[88] Government of Canada, *Achieving Excellence*, op. cit., p. 84

[89] Ibid., p. 46

As cited previously, Langford & al. have made the convincing argument that a Triple Helix of government-industry-university arrangements has contributed to national prosperity (mainly in natural resources) [90] in the first half of the 20th century, up to the mid 1960s. Furthermore, there is more than anecdotal evidence, I have argued, that the DRB has successfully implemented a similar Triple Helix that contributed to the development of innovation fundamental to national security.

The Triple Helix 'stirring' the pool of ideas is a powerful metaphor of the innovation process. Throughout the process, the key ingredients are ideas (invention, manufacturing, marketing, investment, financing, public and private benefits, management techniques) which all have to react together for an invention to 'crystallize' into a true innovation. [91] As any chemical engineer will attest, the speed of a 'reaction' can be accelerated by the use of 'catalyst agents' or, by increasing the temperature or density parameters.

'Catalyst agents' of innovation must have credibility and speak the same language in all three 'helices' of government, industry and academia to be truly efficient. A good example is the cadre of technology advisors supporting the Industrial Research Assistance Program (IRAP) at NRC. It has been argued that their efficiency, remarkable, could still be improved by making a better use of the university sector. [92]

Many well-known arrangements have been experimented to increase the 'temperature and density' of the innovation process: research triangles and other 'Silicon Valley' settings, 'clusters', etc. Interestingly, knowledge people tend to migrate from places where human capital is scarce to place where it is abundant. [93] To continue with the chemical engineering metaphor, the reaction tends to be 'auto-catalytic'. This confirms

[90] Langford, op. cit., p. 22

[91] Ibid., p. 24-25

[92] Ibid., p. 26

[93] Romer, Paul M., "The Origins of Endogenous Growth", J. of Economic Perspectives, Vol. 8, no. 1, p. 3.

Michael Porter's analysis that innovation strives on dynamic local clusters, which in turn attract human capital from abroad and the process become self-sustained. [94]

In summary, the Triple Helix metaphor suggests that Defence R&D Canada has to become more involved in innovation clusters that are taking root in the metropolitan areas where DRDC research centres are located. This will have several benefits for the Department of National Defence and the Canadian economy. These include, *inter alia*:

- Access to a larger pool of technical ideas with 'dual-use' applications,
- More effective use of limited budgets,
- Access to larger pool of talent, and
- Faster commercialization of innovations emanating from defence research, either with defence or dual applications.

The Triple Helix metaphor also indicates that 'catalysts of innovation' will have to be engaged in the development of trilateral arrangement between, industry, DRDC research centres and university. Restrictions due to national security and intellectual property considerations may represent a challenge, but this is manageable.

[94] Langford, op. cit., p. 27

Concluding Remarks

Canada's first priority, in these times of profound economic transformation, should be to invest in knowledge-based initiatives that will create future wealth, while protecting the core elements of our social environments.[95]

It can be posited that one such core element is a robust national defence posture, in tune with the broader strategic environment. Twice in the last century, Canada was found herself ill prepared to deal with the conflicts that broke out in Europe. Twice, the Canadian people mobilized all their resources and successfully met the challenge. The conflicts, which fortunately spared the homeland, also proved to be extraordinary opportunities for the political, economic and industrial maturation of the nation.

War also boosted the development of an indigenous capability in science and technology. Thanks to the foresight and abilities of political, military and scientific leaders of the time, the scientific and technical machinery set in place for World War II was put to the service of the nation.

At the dawn of the 21st century, Canada continues to face the same strategic dilemma, to tackle the same intractable problem of developing an optimum balance between the health, security and economic needs of the citizens. Throughout the 20th century, military and civil R&D had a key role to play in the perpetual quest of the 'holy grail'. Solandt believed in networking and the so-called horizontal management of science across government. He also trusted in the power of knowledge in the economic development of Canada, the glue that makes the whole greater than the sum of its parts.[96] Solandt's ideas perfectly fitted the novel paradigm of the knowledge economy, and the Triple Helix model of innovation.

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[95] Mustard, J. Fraser, "Future Directions in Science and Technology", in Law, op. cit., p. 226

[96] Rothschild, H. "Government/Industry Cooperation on Science & Technology", in Law, op. cit., p. 213-219

Prima facie, it would appear that the 2002 *Achieving Excellence* strategy conforms to the most recent thinking on economic growth. Furthermore, economic indicators are favourable: for the last five years, the Canadian economy has been the most prosperous of the G7 nations, investments in R&D are up, the highest growth rate of all the G7. After decades of trial and error, is it possible that Canada has at last found the 'holy grail' of science strategy? Probably not.

> "[These problems] governments or the country as a whole can never solve. This is part of the business of governance of a nation, of a national economy. It is part of the overall responsibility of governments: we will never put those issues behind us and go back to other things. The world is changing constantly and we'll always have similar problems, perhaps expressed in a different context. That is one thing we will have to draw upon: their persistence and continued relevance."[97]

I believe that the Department of National Defence through its DRDC research arm has the capacity to be part of the solution to this strategic problem of providing security and prosperity for Canadians. On the basis on an empirical socio-political analysis of innovation systems that flourished in Canada in the 20th century, it is recommended that DRDC get aggressively involved in various innovation clusters that are taking root in the metropolitan areas where its research centres are located. It is also recommended that business development advisors be engaged as 'catalysts of innovation' in the Triple Helix of industry, DRDC research centres and university.

[97] Ibid. p. 213-219

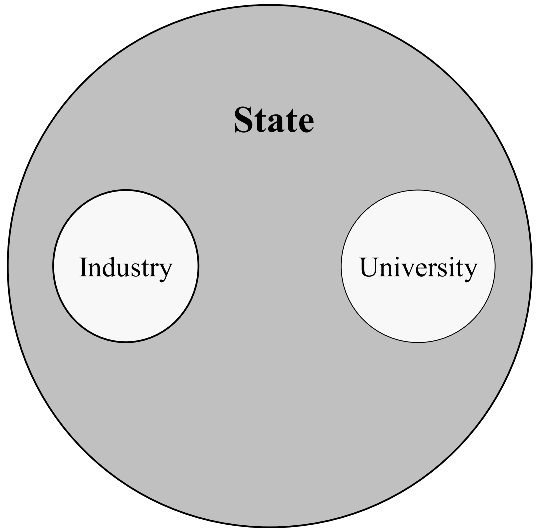

Figure 1. Model of state-run government-industry-university relations[98]

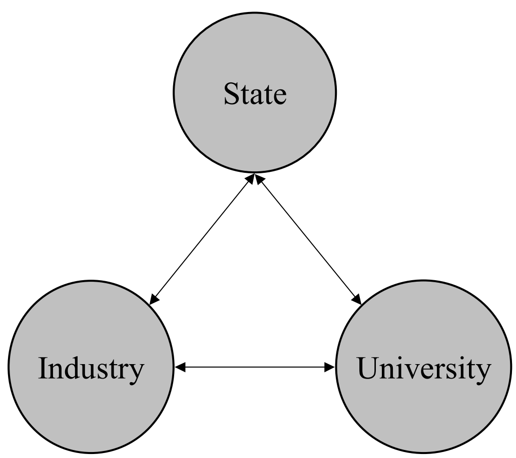

Figure 2. Model of *laissez-faire* government-industry-university relations

[98] All 3 figures from Leydesdorff and Etzkowitz, "Le 'Mode 2'…", op.cit., p. 155-156

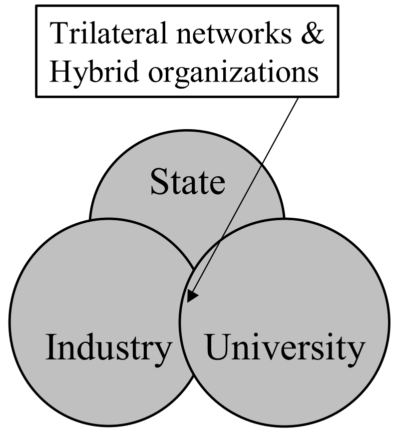

Figure 3. Triple Helix model government-industry university relations

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