

Emergence: Towards a Historiography of Canadian Defence Research during the Second World War

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Résumé de l'article

La Seconde Guerre mondiale a obligé le Canada à se doter de capacités éprouvées de recherche en matière de défense, des capacités qui, avec de nombreux autres apports du Canada, ont d'ailleurs contribué à la victoire en 1945. Bien que des études historiques de ces questions aient pris du temps à démarrer, elles sont devenues de plus en plus populaires. Cette première historiographie vise à décrire comment et pourquoi des écrits sur les efforts de recherche de défense du Canada pendant la Seconde Guerre ont pris de l'ampleur, ainsi que leurs diverses formes de discours et leurs principaux thèmes, controverses et lacunes.

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Abstract

The Second World War forced Canada to become a nation with effective defence research assets, and these assets were among the nation's many contributions to victory in 1945. The historical literature on these developments has been slow to develop though it is now becoming an increasingly popular field of study. This premier historiography attempts to chart how and why the writings on Canada's defence research efforts during the Second World War have grown, its various forms of discourse, and its major themes, controversies, and deficiencies.

Résumé

La Seconde Guerre mondiale a obligé le Canada à se doter de capacités éprouvées de recherche en matière de défense, des capacités qui, avec de nombreux autres apports du Canada, ont d'ailleurs contribué à la victoire en 1945. Bien que des études historiques de ces questions aient pris du temps à démarrer, elles sont devenues de plus en plus populaires. Cette première historiographie vise à décrire comment et pourquoi des écrits sur les efforts de recherche de défense du Canada pendant la Seconde Guerre ont pris de l'ampleur, ainsi que leurs diverses formes de discours et leurs principaux thèmes, controverses et lacunes.

Introduction¹

The Second World War forced Canada to create modern and impressive defence research capabilities. The national application of science, industry, and technology towards military ends was an integral component of Allied victory over the Fascist powers of Europe and Imperial Japan. Canadian politicians, engineers, soldiers, and scientists organized their talents towards this end, and contributed to such projects as the proximity fuse, modern radar, and atomic weapons research, to name but three.² These efforts were primarily directed through two government bodies, the National Research Council (NRC) and the newly formed Department of Munitions and Supply (DMS). In six years of struggle, Canada emerged as a first class defence research power, one that would parley these strengths into the technologically defined Cold War.³

The historiography of this development is problematic to trace for three related reasons. First, defence research is scattered among many historical

fields, including military, political, science, technology, and industry and business history. Each has its own modes of analysis, pedagogical demands, and professional direction. Second, the story of such efforts is often scientifically and technologically complex, thus most historians in traditional fields mentioned have preferred more familiar subjects. Third, the records on defence research have, until recently, been classified.

Despite these difficulties, a sizable body of literature on Canada's defence research efforts exists. The history of Canadian defence research during the Second World War developed through four related, yet distinct, streams. Modest and uncritical official, institutional, and popular accounts dominated the first from the end of the war until the early 1960s. Canadian military historians defined the second stream from the late sixties onward, including defence research aspects in their works on Canada's war effort. Canadian historians of science and technology defined the third stream, which ran parallel to the second through the 1970s. The fourth, from the 1990s to today, coexisting with the second and third, has been defined by commemorative works from modern Canadian defence research institutions who have traced their origins back to their wartime parent. No stream grew in isolation, many works fit between these streams, and all such historical demarcations are subject to challenge. But they provide a starting point.

Prime Minister W.L. Mackenzie King entrusted the National Research Council (NRC)'s C.J. Mackenzie and the Department of Munitions and Supply (DMS)'s C.D. Howe with the responsibility of defence research for the war and this allowed him to avoid concerning himself with the materials of war, which he loathed.⁴ In 1915, Britain had created a committee on scientific and industrial research and recommended that the Dominions do likewise. In 1916 Canada set up an Honorary Advisory Committee for Scientific and Industrial Research, soon to be called the National Research Council (NRC). Given the still latent industrial potential of the nation, by war's end the eleven members of the Committee had only just performed the rudimentary task of creating their organization. The NRC survived the war, and under the guidance of Chairman Dr. Henry Marshall Tory, and his successor Major-General A.G.L. McNaughton, established facilities, including laboratories, in time for the Second World War. When McNaughton returned to active duty in 1939, he maintained his position as president but the role was actually filled by acting president, Dr. C.J. Mackenzie.⁵ Mackenzie's established the NRC as the main research station for all three services by 1941.⁶ He remained president of the NRC until 1952.⁷

The Department of Munitions and Supply (DMS) was created in April 1940 to replace the inadequate War Supplies Board as the chief government department responsible for procuring munitions and organizing the nation's resources toward the war effort. C.D. Howe was given the

portfolio. An acclaimed engineer and engineering teacher with a photographic memory and incredible capacity for work, Howe was given the largest powers of any minister in the war, essentially free to create and control national agencies, and the freedom to do with it as he saw best. Howe excelled at the task.⁸ Howe's energy and leadership was essential to Canada's success on the industrial front.⁹

Stream I: Institutional and Popular Accounts, 1945–1966

Government research institutions wrote the first works on wartime defence research to ensure their efforts were not forgotten. Such legacy works are characterized by generalized accounts of vast projects, complimented by technical data and photographs. While useful, they are uncritical and often brazenly so about the efforts of the organizations during the war.

The NRC War Years

The NRC published the first such work in 1946, with *The War History of the Division of Biology*. This monograph focused on food production, preparation, and refrigeration techniques, critical to British survival after the fall of France and during the Battle of the Atlantic. Other projects included research on biological indicators for war gas, finding natural resource substitutes for war supplies like rubber and alcohol, and developing the "tropicalization" of rations and equipment for Canada's aborted role in the Pacific War. It ends with the discussion of Canada's effort to feed a starving Europe in the aftermath of the war, including solving the problem of canning kosher foods for Europe's desperate Jewish population.¹⁰

Two years later the NRC released its war history of the radio branch, responsible for developing radar. The short narrative tells of Britain's spring 1939 decision to include the dominions in its "RDF" (Radio Detection and Finding) efforts. The head of NRC's radio section, Dr. J.T. Henderson, represented Canada at the first of these meetings in London, and by the start of the war the NRC had, at the behest of President McNaughton, begun its work on radar development for the armed services. This history briefly describes the organization of the branch and its radio model shop section, relations with Munitions and Supply crown corporation Research Enterprise Limited, work done with University of Toronto, McGill, Queen's, and Western, and the various projects undertaken for the armed services.¹¹

These institutional histories are helpful for basic understandings of the division's projects and management, but they provide no critical insight into the problems each division faced. They provide the reader with the basics of the organization's efforts that can, and should, be challenged as more scholarly work on the people, processes, and products associated with the NRC's war work is written.

More rigorous histories of the NRC's war effort were planned, especially the Chemicals Division, which had consumed almost half of the NRC's labour and resources during the war. But the difficulty of translating the complex subject into readable prose confounded the authors of the era. Compounded by the general disinterest of many NRC scientists to take on historical work, the plan of more rigorous NRC histories on the war years would lie dormant for decades.¹²

Similar development occurred in creating the official two-volume history of the Department of Munitions and Supply. Written over four years by department member J. de N. Kennedy, it catalogues the department's phenomenal growth under the stewardship of C.D. Howe.¹³ Defence production and defence research were intimately related throughout the war, and Kennedy's sweeping work catalogues the many research projects connected with the ministry's branches, crown corporations, and controls.

The DMS had two chief defence research branches. The first was the Army Engineering Design Branch, created 9 July 1941, tasked to keep up with changing technical demands in light of battlefield experience. It contained four directorates: Directorate of Signals Design, Directorate of Automotive Design, Directorate of Metallurgy, and Directorate of Tank Design. Contractors did most of the engineering and drafting. Automotive and tank design were of primarily US origin given the need for standardization of parts and US experience in this field. This branch also worked with the Ford Motor Company (Canada) and GM of Canada in the developmental stage to iron out problems before beginning mass production. The Directorate of Metallurgy started the nascent armour creation capability in Canada of armoured steel, working with the Ore Dressing and Metallurgical labs of the Department of Mines and Resources. There was also an Automotive and Tank Production Branch and by 1941, Canada was the main source of mechanized transport in the British Empire. After the fall of France, tank design in Canada moved from piecemeal to complete construction, including the thinly armoured and soon obsolete Valentine tank, among others. These efforts pushed the nation to the limits of its technical infrastructure. The successful management of these research efforts is, alongside production, a large part of DMS's successful war work.¹⁴

The second defence research unit was the Chemicals and Explosives Branch, deeply responsible for the ammunition program's success. Allied War Supplies Corporation, a crown corporation, was created to supervise the construction, management, and operation of chemical, explosive, and ammunition plants. The branch also maintained a Research and Investigations division, which primarily looked at alternative uses of natural resources in chemical explosives, such as using Canadian wood pulp instead of cotton linters as a source of cellulose for nitrocellulose manufacture. The branch managed most industry-critical resources,

including those used in offensive and defensive chemical warfare measures.¹⁵

Kennedy also highlights the projects developed in cooperation with the NRC, who largely provided initial research on projects while DMS worked on production methods. These joint ventures include gun-laying radar (GL radar systems), the RDX super-explosive, No. 58 Wireless set, or "Walkie Talkie," polymers and plastics, optics, taking over the NRC's jet propulsion project in 1943, and more. Canada's atomic power projects at the Montreal Laboratory and Chalk River, as well as the takeover of Eldorado Co. as the chief uranium supplier in Canada, are also briefly covered.¹⁶

But Kennedy's work suffers greatly from how it was written, and large parts of Canada's industrial front were left incomplete.¹⁷ Leadership, the role of personalities, and the complex relationship between research and development and final production are mentioned but not scrutinized, compared, or evaluated. This history is what historian Reinhardt Rürrp classified as "company history," a project that cannot embarrass those it portrays because of its structure and intent; thus much of the story *behind* the story, the how and the why so crucial to historical analysis, remains hidden.¹⁸

In part, Kennedy's work suffers from poor research and limited sources. It was based on project summations made by the organization during the war that he revised, though it is unclear when or where the revisions occurred. It also relied heavily on the booklet prepared by DMS's Director-General of the Publicity Branch, Rielle Thomson, entitled *The Industrial Front*. Parts of this pamphlet, he notes, were incorporated "with little or no change."¹⁹ It was also a rushed and incomplete history. As Kennedy noted,

By 1946 the majority of the personnel of the Department had returned to their peacetime occupations, the files were not easy to find and the Department of Reconstruction and Supply had taken over the remaining duties and functions of the Department of Munitions and Supply. For these and other reasons, it has been extremely difficult to piece together a comprehensive account of the work of some of the units of the Department and any attempt at documentation has been out of the question. I hope the reader will make generous allowances for the shortcomings of some of the chapters.²⁰

Kennedy's work, while not void of value, is merely a survey from a collection of surveys on the DMS's vast war projects, and not a rich, scholarly product.²¹

By the 1960s, popular works on wartime science were being produced, for example, *Scientists at War*, an unofficial history of the NRC's war efforts by Wilfred Eggleston, a respected journalist and NRC enthusiast.

Eggleston's readable work provides a narrative spine to the evolution of Canada's weapons research programmes. Chapters focus on radar; the proximity fuse; RDX and other explosives; atomic energy; service specific research projects (de-gauzing of ships; winterization of equipment); materials and food; and medical research.²²

Eggleston provides the first account of the NRC's chemical war (CW) research and the efforts of Chemical Division chair, E.W.R. Steacie. The creation of the Experimental Station at Suffield, Alberta for testing chemical munitions and gear, and the importance of Dr. Otto Maas of McGill University, one of the chief scientists of the war, is discussed.²³ Suffield's was a critical Canadian contribution to wartime research. Britain did not have the space for the large test areas that chemical war research required. Canada's geography proved, yet again, a tool for security.²⁴ Eggleston fails to mention, however, that Suffield was a joint Anglo-Canadian effort, and among its more important Superintendents were British scientists who had worked at Porton Down CW research establishment.

The book also describes Canada's contribution to more discrete technological developments, from the problems of the "Weasel" winter war vehicle, modified to marshland conditions and used in North West Europe, to the failed attempt to produce the bizarre, British-requested, sea-going "Ice Fortress" known as Habbakuk,²⁵ and many points in between.²⁶ For Eggleston, C.J. Mackenzie, Sir Frederick Banting, Charles Best, Otto Maas, D.J. Henderson, E.W.T. Steacie, S.J. Cook, and others were the dominant personalities of Canada's wartime research.

The difficulties each personality faced within Ottawa, or with allies, or the terrible failures associated with the Royal Canadian Navy's withdrawal for service in the North Atlantic in 1943, are absent. Eggleston is, clearly, an NRC booster, and not a critic. As such, Canada's "middle power" position between their chief allies is described in positive terms of contribution, though relations were far from smooth. British concerns over Canada's intellectual and scientific ability to make meaningful contributions to allied projects, especially towards the British-pioneered radar, were real and had to be overcome. What changed such opinions was Canada's actual performance in radar and RDX production. Eggleston also touches on Canada's fight for critical resources during the period of US neutrality and British scarcity. Humbly, Eggleston argues, via a baseball analogy, that Canada's contribution was, that of

... a player who repeatedly contributes to smart fielding manoeuvres [sic] throughout the game, including participation in a couple of vital triple plays, one who gets up to bat at a critical moment and drives in a run. A player who cannot be described, of course, as the outstanding star of the game, since that honour

belongs to the star pitcher, the "Babe" Ruth of the outfield, but whose assistance stands out as an essential ingredient of victory.²⁷

Like Kennedy, Eggleston vetted his work before his subjects. Indeed, it could not have been written without the consent of Mackenzie, Maas, and the rest of the NRC establishment, which the author also acknowledges.²⁸ Objective analysis and the rigor demanded by scholarly approaches to history are, if not absent, muted in the enthusiastic telling of this tale. Like Kennedy's book, it is a well of information not a foundation stone. Unlike Kennedy, it is a highly readable account of key personalities and policies of Canada's wartime science efforts.

In 1959, Captain D.J. Goodspeed published an official history of the Defence Research Board of Canada, the postwar inheritor of the NRC's defence research obligations and responsibilities. It included a brief summary of the NRC's role during the war, primarily in coordinating the nation's defence research efforts in the services, academia, and industry, and its phenomenal growth. Goodspeed also includes the defence research units of the services developed during the war and would eventually be part of the postwar Defence Research Board.²⁹ This last official history of science in government does not deviate from the arguments of any of the previous accounts to any great measure.

Stream II: Defence Research in Canadian Military History, 1960–1990

By the end of the 1960s, Canadian military historians were taking a keener interest in defence research. Unfortunately, this coincided with military history's decline as a field of study in Canada. As such, wartime defence research developed as a small part of the much grander picture of Canada's war effort, exemplified by John Swettenham's three-volume biography of General A.G.L. McNaughton, one of Canada's first soldier-scientists.

McNaughton's concern and contribution to defence research throughout his prestigious career is charted. C.J. Mackenzie, who wrote the foreword, noted that McNaughton, as president of NRC between 1935 and 1944 was "twenty-five years ahead of his time in his understanding of the part applied science was to play in modern industrial technology."³⁰ His term as NRC president, while initially unpopular with the scientists, nonetheless laid down much of the pre-war preparations the council required to grow into the nation's principal research agency, including increasing its ties to the Department of National Defence.³¹

However, with the General's hands on Swettenham's shoulder, the author rarely challenges the subject. McNaughton argued that his removal as Chief of the General Staff and appointment to president of the NRC was not, as many have suggested, a response to the unpopularity of the labour camps he had organized during the heart of the depression, but a sage and

strategic move by then Prime Minister R.B. Bennett to prepare Canada for a future war with Germany.³²

While the verity of this argument is unsupported by documents, Swettenham demonstrated that McNaughton did organize the NRC to pursue both pure and applied science in projects that directly or indirectly had a military value: the cathode ray direction finder, photographic sciences, ballistics, optics, etc. He also initiated a chemical warfare section to develop counter-measures such as gas masks, fortuitous given the Italian use of poison gas in Abyssinia and Britain's warning that Canada had to supply their own gas masks if war came.³³ Swettenham's book remains the first attempt by a Canadian military historian dealing with the Second World War to include Canada's defence research efforts as part of their story. Two years after the publication of McNaughton's biography, another "official" work would lay claim to being the best overall book on Canada's war policies in the Second World War.

The only other biography of substance on wartime science is Michael Bliss's *Banting*. While best known as the co-discover of insulin, Sir Frederick Banting was also Canada's most popular scientist before his premature death in 1941. Like McNaughton, he feared German advances in science for a coming war in the 1930s. Banting made distinct contributions to the G-suit, and was a firm believer in research into chemical and biological weapons, though his judgment about their value as a weapon was disputed.³⁴ The war work of Charles Best has generated some biographies and historical analysis of Best's role in blood banks and medical science during the war, all of which were more substantial than Banting's war work.³⁵

In 1970, C.P. Stacey published *Arms, Men, and Government: The War Policies of Canada, 1939-1945*. Stacey, Canada's preeminent military historian, took eleven years to write this definitive work, which remains the *magnum opus* of his career. It has yet to be surpassed in its breadth and tactful objectivity assessing the King government's confusing, often contradictory, yet successful war policies, including its review of defence research efforts. These largely concern the army's interest, and this focus is not surprising, since Stacey had originally intended the book to deal with the war policies affecting the army alone.³⁶

Stacey's work dispassionately summarizes the major research projects undertaken by the NRC, DMS, and the services' research and development units in RDX production, the GL Mark IIIC radar system, as well as the chemical warfare unit at the Suffield Experimental Station and atomic research. In short, he gives a scholarly approach to the often dangerous and difficult nature of defence research and defence production that is absent or only suggested in Kennedy's and Eggleston's work, though each of these authors is used as a key source.³⁷ The coverage of the Anglo-Canadian

atomic laboratory in Montreal and Chalk River would soon be surpassed by those with greater access to files and personnel.³⁸ Stacey clearly felt the need to end his book with these efforts to fill out the spectrum of Canada's war effort. Given the book's daunting task, it is instructive that defence research efforts are included at all.

Historian Donald Avery noted that while Stacey was keen to present the contribution Canada made to defence research, evaluating its impact was difficult, if not impossible because it was just that—a contribution. It was “a share, and necessarily in most cases not a major share, in a great and complicated joint effort.”³⁹ Historians may have taken this as a warning, as most Canadian military history on the Second World War places defence research on the periphery of their work.

Service Histories

Unfortunately, the official histories of both the RCN and the RCAF have lagged behind Stacey and his assistants' efforts with the army and the government. It is a sad tale that cannot be recounted here.⁴⁰ So, has defence research been left in the shadow of more dominant and numerous works on operations, doctrine, leadership, and the like in Canadian military history?

Emerging from the Shadows

At first glance, yes. Owen Cooke's eminently useful bibliography of Canada's military history includes many works on Canada's defence research during the Second World War, particularly those concerning radar and atomic energy, but they are not grouped together as a subject unto themselves.⁴¹ It is not surprising, given Cooke's task, that defence research has been subsumed within larger categories. Desmond Morton's more recent and no less ambitious short work *A Military History of Canada* echoes Cooke's approach. Defence research remains, for some military scholars, a small, constituent part of the broader fields of military and political history.⁴²

Publish or Perish

With the waning popularity of national and military history in Canadian academia over the past forty years, it is no shock that defence research, as a subset of military history, has also suffered. Since 1945, few historical publications showed an interest in defence research scholarship. *Canadian Historical Review* featured little military history let alone articles dealing with science and technology in a military context until the late 1970s.⁴³ Robert Bothwell and David Zimmerman both published works on the dynamics between war needs, government action, and relationship with the business and the services. Bothwell focused on government control of uranium mining and production through their crown corporation, Eldorado. His two definitive works on Canada's role in nuclear energy that

emerged from the Second World War are *Nucleus: The History of Atomic Energy of Canada Limited* and *Eldorado: Canada's National Uranium Company*, both of which cover the war years at the Montreal Lab and Chalk River establishment in detail.⁴⁴ Bothwell and William Kilbourn also produced the best current biography of C.D. Howe, providing a personal glimpse into defence research's most important cabinet minister.⁴⁵

Zimmerman's work details the difficult and often antagonistic relationship between the NRC and Royal Canadian Navy (RCN) during the RCN's brutal experience in the Battle of the Atlantic. Zimmerman produced a major monograph on the RCN's technological challenges during the war, *The Great Naval Battle of Ottawa*. Unlike Eggleston, Zimmerman takes a critical stance on the relationship between state agencies such as the NRC, DMS, and Research Enterprises, Ltd., examining the NRC's failures in management and application of science on radar and sonar. C.J. Mackenzie's leadership, while still critical, is also challenged.⁴⁶ While Zimmerman's work was critiqued for some very discrete factual errors,⁴⁷ it also represents a more objective and critical view than the official histories.

Defence research has found more robust representation in more specific academic and professional journals. *Canadian Military History* began in 1990. While focused on traditional military history topics, it has published on technology and its development in war. Most of these discussions are outside the boundaries of this article,⁴⁸ but *CMH* has also championed other defence research issues: for example, political accountability of the RCN's technological failings in 1943; the RCN's challenge with the role of anti-submarine warfare (ASW) in the Battle of the Atlantic; and the development of the "Franks Flying Suit," used to offset the G-forces RCAF and RAF fighter pilots faced throughout the war.⁴⁹ It is hoped that this ethos continues.

Canadian Defence Quarterly (CDQ), a professional military journal, was revived after a forty-year hiatus in 1971 as the professional forum for discussing modern Canadian defence issues. Military history was always included, and until its end in 1998, *CDQ* contained some work of military history. Primarily a modern defence journal, *CDQ* maintained a distinct interest in Canadian defence research matters.⁵⁰ Greg Stewart explored Canada's initial role in jet engine creation through various Crown corporations during and after the war, and its sad decline in the wake of the Avro Arrow debacle.⁵¹ D.A. Fraser described his own wartime recollection of the creation and use of Leigh Light in the RCAF's anti-submarine operations in the North Atlantic.⁵² Historian Marc Milner offered a telling glimpse of the difficulties the RCN faced in recovering from its "technological backwardness" during the Battle of the Atlantic, as it sought new and better asdic-sonar equipment and weapons like the British "hedgehog" mortar system to combat the U-boats.⁵³ The journal's

professional offspring, *Canadian Military Journal*, has maintained this historical and defence research ethos and, hopefully, will soon publish more works that involve the two.⁵⁴

Milner's piece represents a crossover point into the next stream of this historiography. Milner, one of Canada's foremost naval historians, chose to present this piece at the *Canadian Science and Technology Historical Association's* annual Kingston meeting in 1989. Indeed, the burgeoning field of the history of science and technology has provided defence research scholarship a new home.

Stream III: The Growth of Canadian Science and Technology History, 1978–1990

While historical works on science and technology predate the development of these disciplines,⁵⁵ it was not until this past half century that American and then Canadian universities created programmes, departments, and journals that investigated the history of science, technology, and medicine.⁵⁶ Military topics were also examined.⁵⁷

Canada's roots in this field start at the 1972 Montreal meeting of the Canadian Historical Association (CHA), which featured, for the first time, a session on the history of Canadian science. This served as the starting point for what, in 1980, became the *Canadian Science and Technology Historical Association* (CSTHA). This group developed into a professional academic organization, establishing regular conferences and a peer reviewed journal,⁵⁸ *Scientia Canadensis*. From the outset, it published works on defence research during the Second World War. Zimmerman continued his work on the nature of technological change in the RCN, including comparative analysis with the Australian Navy wartime experience.⁵⁹ Work on wartime medical research is growing thanks to work by Canada's Alison Li and the US's Terri Romano on NRC medical work.⁶⁰ Jean-Louis Trudel has written on the war's impact on the development of professional engineering at the University of Toronto, complementing Richard White's recently published history of U of T's Faculty of Applied Science and Engineering.⁶¹ The nation's chemicals history is also represented, including the war years, again focusing on RDX production.⁶² The outrageous, controversial and, in hindsight, silly Habbakuk "ice fleet" project has also garnered more attention now that documents have been declassified.⁶³ There appears no indication that CSTHA will lose its interest in promoting analysis of wartime defence research.

NRC Redux

Many original CSTHA members were NRC archivists, scientists, and historians who worked on correcting the deficiencies in the NRC official histories. In 1976 archivists Bruce Marshall and Alf Ticker established the

NRC History and Archives Project, which would include publishing books on the war work of all the major divisions.⁶⁴ Most were completed by the mid eighties, giving a much more rigorous view of all the divisions.⁶⁵ The exception, again, was the chemistry division.⁶⁶

These archivists also organized the NRC oral history series. These were taped interviews with NRC members and key scientists, including those of the war years. While unavailable for this work at time of writing, they are, by virtue of their existence, a valuable part of the defence research story, though how valuable will depend on the topic, scientists, and quality of answers provided on any of the 100 plus tapes.

In 1975 Mel Thistle, NRC member and writer, released a collection of private and formerly classified letters from C.J. Mackenzie to General McNaughton, 1939–1943. These were Mackenzie's personal attempts to keep McNaughton, still president of the NRC, informed and aware of the council's efforts. The letters were selected with the consent and help of Mackenzie himself, who contributed the introduction and epilogue. This correspondence provides a rare, if limited, look at how Mackenzie ran the NRC. He discusses the difficulties and successes in almost every major division, the strain and benefit of working with allies, the need to concentrate on projects with quick returns to aid the war effort, and a host more. Among the more engaging insights is the NRC's fight with the Civil Service Commission, whose own interests concerning labour, rather than brainpower, clashed with the NRC's need for the best minds and most skilled hands in Canada working on defence research projects.⁶⁷ Mackenzie reveals his views on topics ranging from GL radar development and the RCN,⁶⁸ alliance tension with the US and Britain regarding the perception of quality of Canadian sciences,⁶⁹ and dead-end projects such as Habbakuk, wooden plane production, and camouflage for naval vessels.⁷⁰

The letters are a valuable contribution to the history of Canadian defence research for the insight they provide on Mackenzie's thinking at the time. Zimmerman's work partially refutes the sanguine picture presented here, which is all for the good as Thistle is clearly a champion of Mackenzie. Still, these letters provide fascinating insight into Canada's wartime science management from its chief science tsar.

The saga of NRC's chemical and biological efforts has, on the other hand, found an author outside its institution. John Bryden's *Deadly Allies* is the first major monograph using previously classified documents at the National Archives of Canada as well as the National Research Council to deal with the nation's chemical and biological war effort. Canada's role in creating anthrax and developing various countermeasures is told with enthusiasm. We also get new interpretations on the roles of Mackenzie, Maas, and Banting, all of which are perhaps more controversial than they needed to be. Maas is particularly cited as a figure of perhaps dubious

character. Bryden is good at exploring his personality, though one is left feeling uneasy about the man. A fuller Maas biography that builds on the work done by Eggleston and Bryden will, hopefully, not be long in the making.

The touchstone in the field of defence research in this stream is Donald Avery's 1998 *The Science of War: Canadian Scientists and Allied Military Technology during the Second World War*. Culminating nearly twenty years of work, Avery's book covers most of the major projects Canadian scientists participated in during the war and that have already been touched upon in other works.⁷¹ But Avery gives a readable, scholarly, and objective reading where there had only been general, popular, or controversial accounts of such efforts as the Experimental Station's chemical sprays or anthrax production facilities at Grosse Île, Quebec. The critical and often obfuscated contribution of Canada's universities in defence research is also laid out in detail, particularly the chemical work done at McGill and the University of Toronto. Avery's greatest contribution is his close examination of Alliance politics, which only the Mackenzie-McNaughton wartime letters had previously emphasized. The role of successful liaison scientist in Canada, such as Sir James Chadwick with the atomic energy projects at the Montreal Lab and Chalk River, are presented as critical to Canada's successful participation in the defence research side of the war. Avery argues that Mackenzie envisioned Canada's role in atomic science going beyond the war. To do this required maintaining saliency with its allies so that Canada would maintain access to the best minds, technology, and breakthroughs in harnessing atomic power, while maintaining a focus on immediate war needs. Avery ends his work with discussion of Canada's technical-scientific relations with the Soviet Union and the impact of Soviet espionage in the defence research arena, a rather awkward way to finish his tale.⁷² But that is a minor quibble. *The Science of War* will likely remain the decisive work in the field for some time.

Indeed, Avery's focus on the human relationships involved in defence research gives his work an accessibility often missing in defence research works. The C.J. Mackenzie presented in this work is more sanguine than Zimmerman's portrayal, but it certainly avoids some of the gloss in the NRC histories. More time is spent on the relationship with US research establishments and projects, friction and cooperation with such US science tsars as Vannevar Bush at the National Defence Research Committee (NDRC), later the Office of Scientific Research and Development (OSRD). American work on this relationship clearly places Canada on the periphery of research endeavours, though important parts of the periphery. Avery has helped establish that for the complete story of defence research to be told, it requires a Canadian perspective.

Stream IV: Commemoration

Modern defence research institutions, whose heritage stretches back to those war days, have taken an interest in commemorating as well as remembering these efforts since the 1970s. These works are not scholarly. But given the limited volume of resources on Canadian defence research, many provide a focus and starting point on a series of intriguing aspects of defence research during the war

The most thorough and informative works in this stream are J.W. Mayne's four works on operational research (OR) in the three services during the Second World War, written in the early and late 1970s. Mayne, a member of the Department of Defence's Operational Research and Analysis Establishment (ORAE), originally wrote three histories of OR in the Canadian military, one for each service, in 1970. These were informal institutional histories primarily concerned with understanding how current OR units in each of the services developed. Mayne discussed the major hurdles and successes, reports and activities, that each establishment made. These documents remained classified for internal use until the early 1990s, and much of the data pertains to the postwar period, but the origins of military OR in Canada during the Second World War is covered, although with scant detail. Like Kennedy's work, it is an effort to catalogue rather than analyze the hows and whys of the services' OR efforts.⁷³

By 1978, Mayne had compiled these three efforts into a two-volume work, *Operational Research in the Canadian Armed Forces During the Second World War*. This comprehensive work should serve to guide further research into the totality of military OR as it was developed and practiced in the services.⁷⁴ The RCAF OR units for both East and Western Commands were involved in developing quantitative methods of evaluating operational performances in such areas as bomb damage assessment, efficiency in attacks on U-boats, and answering issues of discrepancies in navigation logs.⁷⁵ The RCN's ORG activities were smaller than the other services, focused primarily on anti U-boat operations, including the development of countermeasures against the German's acoustic torpedo, and, at war's end, processing and communicating information gathered from prisoners taken from U-889, including information on captured German weapons and devices.⁷⁶ The army's ORGs included a gamut of activities and establishments across Canada, and no doubt the army's enthusiasm for OR activities can be attributed to McNaughton's support for such work to be done. There were ten CAORG detachments in total, five in Canada, and five overseas. The activities of the domestic CAORG detachments included cooperation with other government bodies in work ranging from entomological surveys (study of bugs and malaria) to meteorology (using radar to study weather patterns), to training staff in Morse code, gauging the quality of tanks' sight, and many more.⁷⁷

John Longard served as a naval reserve officer in Halifax during the war, where he contributed to the degaussing project (the reduction or elimination of magnetic fields around ships) of the RCN that led to the creation of the Naval Research Establishment (NRE). After the war, he served as the Scientific Advisor to the Commander, Maritime Command, as well as a Scientific Liaison Officer in Washington. Before his death in 1977, Longard completed his own commemorative work of the establishment he had helped build, *Knots, Volts, and Decibels: An Informal History of the Naval Research Establishment, 1940–1967*. Using such sources as NRC scientist George E. Henderson's unpublished manuscript, "Wartime Memories of Canadian Naval Research," as well interviews and photographs from the NRE's own collections, Longard's work covers the role defence research played in the Atlantic theatre with some degree of detail.⁷⁸

While lacking depth, Longard also discusses the friction and problems of the research done at NRE. The pictures of captured U-boats and discussion of Henderson's view of the NRE's trials and tribulations alone make up for Longard's lack of comprehension which, as the title suggests, is not the job of "informal" histories. Longard's work has been complemented by another informal history of the establishment's efforts, 1968–1995,⁷⁹ and indeed many of the postwar defence research establishments have recently looked back and produced documents on their historical journey.

Defence Research and Development Canada (DRDC), Canada's current defence research organization, has made their in-house histories available through their website or via purchase. The history of the Defence Research Establishment Ottawa includes a brief but important summary of the organization's origins in pre-war Chemical Warfare Laboratories under direction the Dr. E.A. Flood of NRC's chemistry division. Included are brief discussions on the pre-war creation of the Respiratory Assembly Plant (RAP) and the charcoal testing laboratory in Ottawa, the gel fuel flame-thrower project, and the 1941 handing over of chemical warfare responsibilities to the Directorate of Chemical Warfare and Smoke, though under Flood's leadership.⁸⁰ But most other commemorative histories, such as those on Canada's Armament Research and Development Establishment (CARDE) in Valcartier, or the Office of Counsellor Defence Research and Development (London), are primarily concerned with the Cold War.⁸¹

No Day Long Enough, edited by George Lindsey and released in 1997, is both a limited and useful commemorative work. This collection of essays and reminiscences of defence research efforts during the war was initiated by Lindsey in the wake of preparing a symposium to honour Dr. Omond Solandt, one of Canada's preeminent defence scientists and science organizers.⁸² The success of the conference and the desire of the contributors to create more documented efforts on the role of Canadian scientists in the Second World War led to *No Day Long Enough*.⁸³

Each chapter and vignette covers some part of the vast array of projects, from the growth and financial support of the NRC during the war, to more discrete technological hurdles involved in radar development, RDX production, and the scientific and technical needs of each service. The atomic power developments and the ever-strange Habbakuk project are also covered. Portions of the work are merely abstracted from the works of Eggleston, Mayne, Longard, Goodspeed, and NRC documents, but given the status of defence research, this is not surprising. In fact, it is encouraging that an attempt was made to bring new and old material together in a rather novel form that includes two professional historians, L.W.C.S. Barnes and Bill Rawlings.

The book's greatest value is in the remembrances, such as I.E. Puddington's work in industrial chemistry to find substitutes to materials made scarce by the war, or P.W. Nasmyth's review of the difficulties the NRC faced in manufacturing their own cavity magnetron. Still, as memory serves as the key primary source here, *No Day Long Enough*, like the NRC histories, must be read with caution and diligence given the sources of data. The picture it presents of the NRC's conduct focuses on success and does not examine failure, and this leads to a one-sided argument that should not be taken as gospel without reading Bothwell or Zimmerman's work on similar subjects.

Conclusion

Canada emerged as a defence research power during six years of war, able to participate and contribute alongside its allies towards victory in 1945. As this historiography shows, this story has only partially been told, and many difficulties in exploring this history remain. Classified documents, difficulty of subject matter, and lack of interest have all contributed to this state. Still, the work that exists suggests that history of defence research in the Second World War is developing steam, albeit slowly, as its literature has grown since 1945.

The four streams of development, from popular and official accounts, to the parallel streams of military history and the history of science and technology, to the renewed interest of institutions in commemorative histories, have, thankfully, a forward momentum. Hopefully this momentum will help inspire others to correct some of the major holes in the historiography.

Of immediate concern is the lack of professional biographies on chief scientists of the war. McNaughton, Banting, and Best have been given historical treatment, but it will be impossible to assess the complete picture of Canada's defence research efforts without comprehensive investigations into the lives of C.J. Mackenzie, Otto Maas, John T. Henderson, E.W.R. Steacie, and others.

The Department of Munitions and Supply also needs more thorough treatment than can be given in this paper. The difficulty, of course, lies in getting business and official records from private and public archives, no easy task given business's general reluctance to allow anyone access to their records without a say in the final product: the fear of writing "company histories" remains. But the activities of such bodies as Research Enterprises Limited or the Army Engineering Research Branch are vital ingredients in knowing how Canada produced relevant war machines. Again, access to records may be difficult, indeed impossible.⁸⁴ Until we have more data, we are stuck with Kennedy's assertions, which, for all we know, may be diluted, contradictory, or wrong.

The historiography of these efforts, though, has a more positive trajectory. Military history and the history of science and technology in Canada have provided forums for those with an interest in research and writing on defence research topics. The difficulties of studying defence research in Canada during the Second World War are not insurmountable. Scholars of the history of technology have created a body of literature on the critical importance of contextual factors in scientific and technological development.⁸⁵ Their emphasis on the power of personality and the influence of institutional and cultural factors in technological development may provide new tools of analysis and modes of inquiry for young students studying Canadian defence research. For instance, students might assuage the difficulty of the subject matter and create richer intellectual products on topics, like radar development at the NRC or the NRE, which have already been initiated into the field, by comparative views on service culture between Canada, Britain, and or the US. Whatever steps they take, new researchers and writers will be adding to a growing historiography that has developed from a peripheral element to a relatively new field of study, one that has grown in quality and variety through various streams of historical inquiry.

Notes

1. This paper could not have been written without the help of the following: at the Royal Military College of Canada, Lt. Col. (Ret'd) John Marteinson and the entire War Studies 612/512 Canadian Defence Policy class, Drs. Mike Hennessy, Sean Maloney, and Andrew Godefroy; at the University of Toronto, Dr. Robert Bothwell; the entire membership of the Canadian Science and Technology Historical Association, in particular Don Phillipson and George Henderson; the list members of H-Technology-Science-Medicine; at the Command and Staff College, Directorate of Land Strategic Concepts, Dr. Fred Cameron. I'd also like to thank Drs. George Lindsey, Cecil Law, and Archie Penney for their help in my research. All errors of fact or argument, however, are the author's alone.
2. The British had pioneered the technology that we now call radar in the late 1930s, as a means of defence against the growing threat of German airpower. It proved to be the decisive technology of victory during the Battle of Britain, allowing successful and accurate anti-aircraft defences to turn the tide of those desperate

years. The military's desire for an accurate fuse that would trigger a shell's explosive power while nearing its target, thus sending explosive debris in the target's path, was hampered by the technical difficulty such a device imposed. The successful development of the proximity fuse in 1943, an outgrowth of radar research, was one of the most difficult technological hurdles of the war. The most difficult technological feat of the entire conflict was, of course, the development of an atomic weapon. After a Herculean effort, such devices became reality only six years after the discovery of fission by German scientists in 1938. For each technology's story see, in order, Robert Buder, *The Invention that Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution* (New York: Touchstone, 1998); James Phinney Baxter III, *Scientist Against Time* (Boston: Little, Brown and Company, 1952), 221–243; Richard Rhodes, *The Making of the Atomic Bomb* (New York: Touchstone, 1988). A recent popular account that integrates Canada's efforts into the larger picture of Allied defence research efforts is Tom Schachtman, *Laboratory Warriors: How Allied Science and Technology Tipped the Balance in World War II* (Perennial: New York, 2003).

3. This argument is made in light of Canada's success in establishing a credible postwar defence research body, the Defence Research Board, in 1947. D.J. Goodspeed, *A History of the Defence Research Board of Canada* (Ottawa: Queen's Printer and Controller of Stationary, 1958), 7–27.
4. King was also something of a pioneer in industrial relations, a field he worked in professionally in the US for the Rockefellers during the First World War, again raising criticism, somewhat justified, of King's lack of any martial vigour. See Jonathan Vance, *Death So Noble: Memory, Meaning and the First World War* (Vancouver: UBC Press, 1997), 122–25.
5. A Harvard graduate, Mackenzie had served in the Great War with distinction, earning the Military Cross, studied engineering under C.D. Howe at Dalhousie University, and re-instituted the School of Engineering at the University of Saskatchewan, where he had been dean. Indeed, it was both Howe and McNaughton's recommendation that got Mackenzie, a Conservative, the position at NRC.
6. C.P. Stacey, *Arms, Men and Government: The War Policies of Canada, 1939–1945* (Ottawa: Queen's Printer, 1970), 508.
7. The history of the NRC is instructively covered in Donald J.C. Phillipson, "The National Research Council of Canada: Its Historiography, its Chronology, its Bibliography," *Scientia Canadensis* 15:2 (1991), 177–200. There is, shamefully, no biography on Mackenzie. His disposition, which has been a point of argument among some historians, was described to the author from one of Mackenzie's contemporaries, Archie Pennie, an RAF pilot trained under the British Commonwealth Air Training Programme during the Second World War, and defence scientist with the Defence Research Board during the Cold War (personal communication, 19 November 2004).
8. J. de N. Kennedy, *History of the Department of Munitions and Supply: Canada in the Second World War? Volume I. Production Branches and Crown Companies* (Ottawa: King's Printer and Controller of Stationary, 1950), xvii.
9. The best biography on Howe remains Robert Bothwell and William Kilbourn, *C.D. Howe: A Biography* (Toronto: McClelland and Stewart, 1979).
10. National Research Council, *The War History of the Division of Biology* (Ottawa: n.p., 1946), 8, 29–31, 72–104, 123–140, 142. In 1955, F.T. Rosser and M.W. Thistle, both members of the NRC's division of applied biology, released *War*

- Stories from Biology*, a scrapbook collection of previously published popular articles from 1944–1945, charting the division's programmes under director W.H. Cook. They read, as intended, as a "popular" account of the *War History*'s efforts mentioned above. It was, as far as the author knows, the only popular account attempted. Canada's continuing role in developing its own natural resources and its own large agriculture business may have generated enough interest for the project. F.T. Rosser and M.W. Thistle, *War Stories from Biology: A "Popular" Account of the Work of the Division of Applied Biology, of the National Research Council, During the Second World War* (n.p. 1955).
11. The rest of the book contains photos of the branches, factories, and branch equipment (various antennas for different radar wavelengths, measuring equipment) graphs of the division's growth during the war and lists of the branches key reports for future consultation. National Research Council, *The War History of the Radio Branch* (Ottawa: n.p., 1948),
 12. Personal communication with Donald J. Phillipson, National Research Council Historian, 25 November 2004.
 13. J. de N. Kennedy, *History of the Department of Munitions and Supply: Canada in the Second World War? Volume I. Production Branches and Crown Companies* (Ottawa: King's Printer and Controller of Stationary, 1950); idem, *Volume II. Controls, Services and Finance Branches, and Units Associated with the Department* (Ottawa: King's Printer and Controller of Stationary, 1950).
 14. Kennedy, *Volume I*, 52–53, 62, 69–70, 73, 92.
 15. Other branches of note that had defence research elements: Defence Projects Construction; General Purchasing Branch; Gun Production Branch, divided into Guns (Army) Division, Guns (Navy) Division, Small Arms Division, and Instrument Division; Munitions Contract Branch; Naval Armament and Equipment Branch; Naval Shipbuilding Branch; and Priorities Branch. See Kennedy, *Volume I*, 104, 132–134, 204, 229.
 16. Kennedy, *Volume I*, 68, 121, 157, 167, 177, 179, 270, 295, 336–44, 338, 345, 401, 407; see also idem, *History of the Department of Munitions and Supply: Canada in the Second World War? Volume II. Controls, Services and Finance Branches, and Units Associated with the Department* (Ottawa: King's Printer and Controller of Stationary, 1950), 455–456.
 17. See Mike Hennessy, "The Industrial Front: The Scale and Scope of Canadian Industrial Mobilization during the Second World War," in *Forging a Nation: Perspectives on the Canadian Military Experience*, Bernd Horn, ed. (St. Catharines, ON: Vanwell Publishing, 2002), 135. Bothwell and Kilbourn provide a much more integrated and scholarly look at the Department through the actions of C.D. Howe. See *C.D. Howe: A Biography*, 128–260.
 18. Quoted in John Staudenmaier, *Technology's Storytellers: Reweaving the Human Fabric* (Cambridge and London: Published jointly by the Society for the History of Technology and the MIT Press, 1985), 146, 165, 175.
 19. Kennedy, xviii.
 20. Kennedy, xvii.
 21. See Hennessy, "The Industrial Front: The Scale and Scope of Canadian Industrial Mobilization during the Second World War," in *Forging a Nation: Perspectives on the Canadian Military Experience*, Bernd Horn, ed. (St. Catharines, ON: Vanwell Publishing, 2002): 135, 154, n. 3.
 22. Wilfrid Eggleston, *Scientists at War* (London: Oxford University Press, 1950). Eggleston would also write one of the first histories of nuclear power in Canada. See Eggleston, *Canada's Nuclear Story* (Toronto: Clarke, Irwin, 1965).

23. The Experimental Station would survive the war and become, according to one of its former employees, "the largest farm in Canada dedicated to defence research," for the Defence Research Board (personal communication with Cecil Law, 14 October 2004).
24. Eggleston, 21, 22, 71, 103, 104, 110, 200–09. After the war, when Maas was recommended for the Gold Medal of the Professional Institute of the Civil Service, a letter signed by Lieutenant-General Charles Foulkes, the Chief of the General Staff, and Brigadier G.P. Morrison, Deputy Master General of the Ordnance, contained these words of praise: "... although the enemy power had, for many years, studied, developed, and produced the means for waging chemical warfare on a scale which dwarfed the pre-war Allied resources, its use was never attempted. In a surprisingly short time span, the Allied defensive technique and subsequent counter-offensive resources had developed into an effective threat that the enemy dared not risk to invoke. In this achievement, the name of Dr. Maas ranks second to none among the Allied scientists whose joint efforts rendered impotent a weapon that otherwise the enemy might well have used decisively" (qtd. in Eggleston, 101).
25. A misspelled biblical reference to the book of Habakkuk.
26. Eggleston, 97–100, 111–112, 153–159, 240, 247, 250.
27. *Ibid.*, 2.
28. *Ibid.*
29. The army maintained Canadian Armament Research and Development Establishment (CARDE) at Valcartier, Quebec; the Vehicle Design and Development Establishment in Ottawa (dealt with the Weasel); the Chemical Warfare Laboratories (eventually assuming formal control from the NRC); the Canadian Signals and Radar Development Establishment, and Inter-Service Research and Development Establishment (General Stores); and the No. 1 Airborne Research and Development Centre at Shilo, Manitoba. The RCN initially used the NRC as their research and development body for their Naval Research Establishment (NRE) at Halifax, but by 1943 had assumed more direct control of these functions. The RCAF had five major research centres: a Test and Development Establishment at Rockcliffe, near Ottawa; a Winter Experimental Establishment at Edmonton; a Photographic Research Establishment and a Radio Wave Propagation Unit at Ottawa; and the Institute of Aviation Medicine in Toronto. The RCAF also became interested in the Flight Research Station based at Arnprior, ON, and operated by the NRC. Goodspeed also mentions the joint Canadian/US research project known as the War Disease Control Station at Grosse Île, Quebec, and the Chemical Warfare Experimental Station in Suffield "which had, for most of the war, been the joint responsibility of Canada and the United Kingdom" (Goodspeed, 7–9).
30. John Swettenham, McNaughton, *Vol. I, 1887–1939* (Toronto: The Ryerson Press, 1968), x.
31. *Ibid.*, 318–342.
32. *Ibid.*, 324.
33. *Ibid.*, 328.
34. Michael Bliss, *Banting: A Biography* (Toronto: McClelland and Stewart, 1984; reprinted 1985), 254–297.
35. Henry M. Best, *Margaret and Charley: The Personal Story of Dr. Charles Best, Co-Discoverer of Insulin* (Toronto: Dundurn Group, 2003); Richard W. Kapp, "Charles H. Best, the Canadian Red Cross Society, and Canada's First Blood Donation Programme," *Canadian Bulletin of Medical History* 12 (1995), 27–46.

36. Then Minister of National Defence, Brooke Claxton, the man who prophesized that no one would want to read about the Second World War after 1948, suggested the book instead include the nation's war policies in total. This greatly increased the workload and length of the project. For the story behind Stacey and Claxton's debates over all the official histories, see C.P. Stacey, "The Life and Hard Times of an Official Historian," CHA 51:1 (March 1970), 21-47; idem, *A Date with History: Memoirs of a Canadian Historian* (Ottawa: Deneau, 1983), 197, 215, 241.
37. Indeed, Stacey used many of the works already cited, including Goodspeed, but not to the exclusion of various primary sources. See Stacey, *Arms, Men and Government*, 64-164.
38. C.P. Stacey, *Arms, Men, and Government: The War Policies of Canada, 1939-1945* (Ottawa: Queen's Printer, 1970), 507-28.
39. Quoted in Avery, *The Science of War, Canadian Scientists and Allied Military Technology During the Second World War* (Toronto: University of Toronto Press, 1998), 9.
40. Thankfully, one that has ended. The Directorate of History and Heritage at the Department of National Defence has been working since the early eighties to finish the official histories of each service in total. Again, given the scope of each project, it is unfortunate but not surprising that defence research does not play a major part in their story. See Stacey, *A Date with History*, 169-265.
41. The 1997 edition, for instance, includes W.E.K. Middleton's history of radar development in the Naval section of the National Research Council, while Wilfrid Eggleston's *Scientists at War and Canada's Nuclear Story* are kept within the Land Forces section. See Owen Cooke, *The Canadian Military Experience, 1867-1995: A Bibliography, 3rd Edition* (Ottawa: Directorate of History and Heritage, Department of National Defence, 1997), 90, 258.
42. The book's "further reading" list, like Morton's own work, focuses on the broader issues of political, social, and military people, events, and actions. Canadian defence research, even during the technologically defined Cold War, does not warrant any unique space in Morton's review of critical texts on the Canadian military experience, with the titillating exception of the Avro Arrow debacle. Desmond Morton, *A Military History of Canada*, 303-10.
43. Alan Watt, review of *Nucleus: The History of Atomic Energy Canada*, by Robert Bothwell, *Canadian Historical Review*, 70:3 (September 1989), 388-89; Graham Taylor, review of *Eldorado: Canada's National Uranium Company*, by Robert Bothwell, *Canadian Historical Review* 71:3 (September 1985), 429-30; Dale Thomson, review of *C.D. Howe: A Biography*, by Robert Bothwell and William Kilbourn, *Canadian Historical Review* 61:3 (1980), 410-12; John Parry, review of *National Research in Canada: The NRC, 1916-1966*, by Wilfred Eggleston, *Canadian Historical Review* 60:4 (1979), 514-15; Bruce Sinclair, review of *The Mackenzie-McNaughton Wartime Letters*, edited by Mel Thistle, *Canadian Historical Review* 58:1 (1977), 83-84; H. Blair Neatby, review of *Arms, Men, and Government: The War Policies of Canada, 1939-1945*, by C.P. Stacey, *Canadian Historical Review* 53:1 (1972), 73-74; J.M. Hitsman, review of *Scientists at War*, by Wilfrid Eggleston, *Canadian Historical Review* 1 (1951), 89. Hitsman also wrote an engaging look at "defence research" during the War of 1812, "David Thompson and Defence Research," *Canadian Historical Review* 40:4 (December 1959), 315-18.

44. Robert Bothwell, *Eldorado: Canada's National Uranium Company* (Toronto: University of Toronto Press, 1984); idem, *Nucleus: the History of the Atomic Energy of Canada Limited* (Toronto: University of Toronto Press, 1988).
45. Robert Bothwell and William Kilbourn, *C.D. Howe: A Biography* (Toronto: McClelland and Stewart, 1979), 168–69, 205, 213.
46. David K. Zimmerman, "The Royal Canadian Navy and the National Research Council, 1939–1945," *CHA* 69:2 (1988), 203–221; idem, *The Great Naval Battle of Ottawa* (Toronto: University of Toronto Press, 1989). Zimmerman also wrote about the difficult process of radar design at the crown corporation Research Enterprises Limited. Zimmerman, "Radar and Research Enterprises Limited: A study of wartime industrial failure," *Ontario History* 80:2 (June 1988), 121–42.
47. Ruth Fawcett, review of *The Great Naval Battle of Ottawa*, by David Zimmerman, *Scientia Canadensis* 13:2 (Fall/Winter 1989), 132–34.
48. These articles deal with operational and tactical use of military equipment or operational research in the field. See Terry Copp, "Operational Research in 21 Army Group," *Canadian Military History* 3:1 (1994): 71–84; idem, "Counter-Mortar Operations in 21 Army Group," *CMH* 3:2 (1994), 45–52; John Grodzinski, "'Kangaroos at War': The History of the 1st Canadian Armoured Personnel Carrier Regiment," *CMH* 4:2 (1995), 43–50; Hugh Henry, "The Calgary Tanks at Dieppe," *CMH* 4:1 (1994), 61–74; George Lindsey, "Some Personal Recollections of Army Operational Research in World War II," *CMH* 4:2 (1995), 69–74.
49. Richard Mayne, "Bypassing the Chain of Command: The Political Origins of the RCN's Equipment Crisis of 1943," *CMH* 9:3 (2000), 7–22; Douglas McLean, "Confronting Technological and Tactical Change: Allied Anti-Submarine Warfare in the Last Year of the Battle of the Atlantic," *CMH* 7:3 (1998), 23–34; Dean Oliver, "The RCN at War," *CMH* 2:1 (1993), 138–140; George Smith, "The Franks Flying Suit in Canadian Aviation Medical History, 1939–1945," *CMH* 8:2 (1999), 35–41.
50. Guy J.C. Bertrand, "Canadian Military Research and Development: Success—Failings—Prospects," *CDQ* 1:1 (Summer, 1971), 19–25; A.M. Fordyce, "How it All Started: The Goforth Paper," *CDQ* 1:4 (Spring, 1972), 15–16; Archie Pennie, "The Defence Research Board: A Quarter Century of Achievement," *CDQ* 1:4 (Spring, 1972), 1–16; Archie Pennie, "On What Happened to DRB," *CDQ* 4:2 (Autumn 1974), 50–52. *CDQ* also contained many impressive articles on war and technology in different periods. See V.P. Ignatieff, "The Capture of the Main Chemical Experimental Facilities of the German Army: A Personal Memoir," *CDQ* 12:1 (Summer 1982), 43–46; John F. Wallace, "The First Armoured Cars: A Very Canadian Story," *CDQ* 11:3 (Winter 1981–1982), 39–40; Sean Maloney, "The Canadian Army and Tactical Nuclear Warfare Doctrine," *CDQ* 23:2 (December 1993), 23–29.
51. Greg Stewart, "Canada and the Development of the Aircraft Jet Engine: Present at the Creation? But Not Long Enough Thereafter," *CDQ* 9:1 (Summer 1979), 48–56.
52. D.A. Fraser, "Present at the Creation: Recollections of the Very First Anti-Submarine Operations Using Leigh-Light," *CDQ* 9:4 (Spring 1980), 43–46.
53. Marc Milner, "The Implications of Technological Backwardness: The Royal Canadian Navy 1939–1945," *CDQ* 19:3 (Winter 1989), 46–52.
54. Lieutenant-Colonel (Ret'd) John Martenson, who edited or co-edited *CDQ* throughout its existence has commented that many articles on defence research were submitted over the years, but most of them were so technical that they would

- not appeal to the intended audience. Such points remind us of the role and responsibility of the writers of defence research history; they must balance the technical or scientific nature of their work and the need for an accessible narrative. Personal communication with John Marteinson, 1 December 2004.
55. The most comprehensive review of the history of military technology remains Barton Hacker's seminal essay "Military Institutions, Weapons, and Social Change: Toward a New History of Military Technology," *Technology and Culture* 35 (1994), 768–834.
 56. Journals such as *Minerva*, *Isis*, *History of the Biological and Physical Sciences*, and *Technology and Culture* remain the landmarks in the field. For the American development of the history of technology, see Robert S Woodbury, "The Scholarly Future of the History of Technology," *Technology and Culture* 1 (Fall 1960), 421–25; Thomas P. Hughes, "Emerging Themes in the History of Technology," *Technology and Culture* 20 (1979), 697–711 [Published originally in German in *Geschichte und Gesellschaft* 4 (1978): 258–71]; John M. Staudenmaier, "What SHOT Hath Wrought and What SHOT Hath Not: Reflections on Twenty-five Years of the History of Technology," *Technology and Culture* 25 (1984), 713–17.
 57. Alex Roland, "Technology and War: A Bibliographic Essay," in *Military Enterprise and Technological Change: Perspectives on the American Experience*, Meritt Roe Smith, ed. (Cambridge and London: MIT Press, 1985), 347–79.
 58. The full story of the group's development is recounted in R.A. Jarrell and N.R. Ball, "The Study of the History of Canadian Science and Technology," in *Science, Technology, and Canadian History*, R.A. Jarrell and N.R. Ball, eds. (Waterloo: Wilfred Laurier Press, 1978), 1–8; and Tom Nesmith, "Commentary: Reflections on the State of the History of Canadian Science and Technology," *History of Science and Technology in Canada Bulletin* 3:4 (August 1978), 5–6. For more details, see the CSTHA website: [www.er.uqam.ca/nobel/r20430/ahstc-cstha/english/home.html].
 59. David Zimmerman, "A First Step in Comparative History: The Royal Australian and Canadian Navies and High Technology in the Second World War," *Scientia Canadensis* 17:1 & 2 (1993), 255–267. Idem, "The Organization of Science for War: The Management of Canadian Radar Development, 1939–1945," *Scientia Canadensis* 10:2 (Autumn/Winter 1986), 93–108.
 60. Alison Li, "Expansion and Consolidation: The Associate Committee and the Division of Medical Research of the NRC, 1938–1959," *Scientia Canadensis* 15:2 (1991), 89–103; Terrie M. Romano, "The Associate Committees on Medical Research of the National Research Council and the Second World War," *Scientia Canadensis* 15:2 (1991), 71–88.
 61. Jean-Louis Trudel, "Born in War: Canada's Postwar Engineers and Toronto's Ajax," *Scientia Canadensis* 21 (1997), 3–27. White's work also covers the war years. Richard White, *The Skule Story: The University of Toronto Faculty of Applied Science and Engineering* (Toronto: University of Toronto Press, 2002), 147–206.
 62. James P. Hull, Ian D. Rae, and Andrew T. Ross, "The Development of Chemical Industries in Australia and Canada, 1850–1950," *Scientia Canadensis* 17:1 & 2 (1993), 205–231.
 63. Susan B.M. Langley, "OPERATION HABBAKUK: A World War II Vessel Prototype," *Scientia Canadensis* 10:2 (Autumn/Winter 1986), 119–131. Lorne Gold, an employee of the NRC, was tasked with writing a clear history of the

- project when most of the files were declassified in the late 1980s. The result was a book light on narrative and rich in documents, which traced the project from its strange beginning to its sad end. Lorne Gold *The Canadian Habbakuk Project: A Project of the National Research Council of Canada* (Cambridge, UK: International Glaciological Society, 1993).
64. Physics; Physics—Radio Branch; Physics—Mechanical Engineering (inc. Aerospace); Chemistry; Biology; Research Information; Extramural grants function.
 65. W.E. Knowles Middleton, *Physics at the National Research Council of Canada, 1929–1952* (Waterloo: Wilfrid Laurier University Press, 1979); idem, *Radar Development in Canada: The Radio Branch of the National Research Council of Canada, 1939–1946* (Waterloo: Wilfrid Laurier University Press, 1981); *Mechanical Engineering at the National Research Council of Canada, 1929–1951* (Waterloo: Wilfrid Laurier University Press, 1984); N.T. Gridgeman, *Biological Science at the NRC: The Early Years to 1952* (Waterloo: Wilfrid Laurier University Press, 1979); D.J.C. Phillipson, *Associate Committees of the NRCC, 1916–1974* (Ottawa: National Research Council of Canada, 1985); D.J.C. Phillipson, *International Scientific Liaison and the NRCC, 1916–1974* (Ottawa: National Research Council of Canada, 1985).
 66. The same difficulties of lack of interest and complex nature of the subject remained. While various attempts were made after their initial projects were complete, the NRC archivists who started the project were unable to finish the chemistry division's story. Years later, the NRC hired one of the original project members, Don Phillipson, to review the work and prepare a blueprint for completions. Phillipson took on the task and charted a course for the completion of the project only to find institutional resistance and lack of interest had taken root. The chemistry division's story remains, sadly, unfinished as of this writing. Personal communication between the author and Donald Phillipson, 25 November 2004.
 67. Mel Thistle, ed., *The Mackenzie–McNaughton Wartime Letters* (Toronto: University of Toronto Press, 1975), 40.
 68. Thistle, 25, 43, 62.
 69. Thistle, 51, 79–80, 85, 92.
 70. Thistle, ix–xxiv.
 71. Donald Avery, *Scientists at War: Canadian Scientists and Allied Military Technology during the Second World War* (Toronto: University of Toronto Press, 1998).
 72. Richard Rhodes has made this argument concerning his own work on nuclear weapons. In the research for the first book, *The Making of the Atomic Bomb*, Rhodes realized that the wealth of data he had collected on Soviet infiltration of the Manhattan project was too critical to be left as a small part of a big picture and thus constituted one of the major themes in his second work, dealing more specifically with the development of the hydrogen bomb. See Rhodes, *Dark Sun: The Making of the Hydrogen Bomb* (New York: Simon & Schuster, 1995), 577–588.
 73. J.W. Mayne, "History of Canadian Army Operational Research Establishment," Department of National Defence, *Canada, Defence Research and Analysis Establishment Report No. 15, Volume I & II* (April and June, 1970).
 74. The first volume covers in some detail each service's operational research section (ORS) or group (ORG), how they developed, and their main projects. Mayne makes it clear that NRC scientists played an important role in these efforts, often

- being dispatched to help each service develop this new scientific approach to military affairs. The second volume contains annexes and appendixes that include interviews with NRC scientists like Henderson, Johnstone, and many others who worked with the services in an OR capacity. The annexes include lists of each service's main OR reports, though most are from the naval side of the war. J.W. Mayne, "Operational Research in the Canadian Armed Forces During the Second World War," two volumes, Department of National Defence, Canada, *Operational Research and Analysis Establishment*, Report No. R68 (June 1978).
75. Mayne, 10–61.
 76. Mayne, 62–74.
 77. Mayne's more pressing concerns on CAORG activities are, however, on the roots of postwar actions and establishments and thus cannot be dealt with here. Mayne, 77–128.
 78. Each chapter examines a discrete issue, beginning with work done during the war and onward. The NRE's war work described includes the capture of German U-boats U-190 and U-889, mentioned before in Mayne's work, countermeasures to acoustic mines, degaussing against magnetic mines, harbour defence, and oceanography. John R. Longard, *Knots, Volts, and Decibels: An Informal History of the Naval Research Establishment, 1940–1967* (Dartmouth: Defence Research Establishment Atlantic, 1993).
 79. Robert L. Geade and Harold M. Merklinger, *Seas, Ships, and Sensors: An Informal History of the Defence Research Establishment Atlantic, 1968–1995* (Dartmouth: Defence Research Establishment Atlantic, 2002).
 80. Suzanne Board, *A Brief History of the Defence Research Establishment Ottawa, 1941–2001* (Ottawa: Defence Research Establishment Ottawa, 2002), 2–4.
 81. D.E. Holness, *The Office of the Counsellor Defence Research and Development: London (CDRD[L]): A Brief History, 1940–1993* (Ottawa: Directorate of International Research and Development, CDAD/DND, 1994); H.P. Tardiff, *DREV, 1945–1995: Fifty Years of Progress* (Ottawa: Department of National Defence, 1995).
 82. Solandt was a Gold medal-winning scientist and physiologist who had trained with Charles Best at the University of Toronto during the 1930s. He was in London when the Second World War began and initially served with the London Blood Bank during the Battle of Britain. His keen intellect, thoroughness, and versatile mind led him to work with the Physiological Laboratories at the Armoured Fighting Vehicles in Lulworth, England, where he solved some of the physiological problems associated with tank crews passing out from gun and engine fumes. He then was posted as Deputy Superintendent of the British Army Operational Research Group under South African physics and lightening studies pioneer Sir Basil Schonland. Schonland left the BAORG after the Normandy invasion to serve as Scientific Advisor to General B.L. Montgomery and Solandt became Superintendent until the end of the war. In the fall of 1945, he served as a Canadian Colonel in the British units assigned to the United States Strategic Bomb Survey (USSBS) investigating the structural and medical effects of the atomic bombs on Hiroshima and Nagasaki. In 1946, he returned to Canada, being selected to be the first Chairman of the Defence Research Board of Canada. He left the DRB in 1956, and pursued various important jobs and projects until his death in 1993. He was truly a Canadian original. See David Grenville, "Omond Solandt: A Biographical Sketch," in *Perspectives in Science: The Legacy of Omond Solandt*, George Lindsey, Cecil Law, and David Grenville, eds. (Kingston: Queen's Quarterly Press, 1994), 1–18.

83. George Lindsey, ed., *No Day Long Enough: Canadian Science in the Second World War* (Toronto: Canadian Institute for Strategic Studies Press, 1997).
84. Lieutenant-Colonel (Ret'd.) John Marteinson recalled in his research for the history of the Canadian Armoured Corps that many of the original documents on tank production in Canada, originally housed at the Canadian Forces Base Borden's museum, had to be moved to make way for current base needs. But they could not find a home quick enough and they ended up being destroyed. This tale should make any historian cringe and increase urgency towards searching for other repositories of documents integral to understanding Canadian defence research efforts in the Second World War.
85. John Staudenmaier, *Technology's Storytellers: Reweaving the Human Fabric* (Cambridge and London: Published jointly by the Society for the History of Technology and the MIT Press, 1985); idem, "Rationality, Agency, Contingency: Recent Trends in the History of Technology," *Reviews in American History* 30 (2002), 168–181.