OPERATIONAL RESEARCH AND THE CANADIAN CORPS, 1915-1918

LA RECHERCHE OPÉRATIONNELLE ET LE CORPS CANADIEN, 1915-1918

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Abstract

This thesis examines the operational research conducted by the Canadian Corps during the First World War. It challenges the argument presented by most historians of operational research, who contend that the discipline originated with the 1935 Tizard Committee and came to fruition during the Second World War. This thesis expands upon the initial inquiry performed by scholars J.S. Finan and W.J. Hurley in a 1997 journal article and finds that three specialized staffs in the Canadian Corps headquarters – the counter-battery staff office, Canadian Corps Gas Services, and the Canadian Machine Gun Corps – conducted operational research with varying degrees of rigour. None of these staffs ever used the term "operational research" to describe their scientific studies. However, they were undoubtedly its practitioners through their innovating, trialling, experimentation, and dissemination of knowledge – the four pillars of the discipline. Artillerymen, gas officers, and machine-gunners applied science to their respective weapon systems and, in doing so, made them as efficient and effective as possible. And they shared best practices with other formations in the British Expeditionary Force. Through their studies, the Canadian Corps protected its soldiers from the worst effects of chemical weapons, and used gas, machine-gun barrages, and counter-battery fire to attrite the German Army and strike their most important systems. Several of the studies conducted by these staff officers were mirrored by investigations carried out by No. 2 Operational Research Section during the Second World War. As a result, this study offers a new interpretation of adaptation to technology, scientific approach to operations, and learning within the Canadian Corps during the First World War.

Résumé

Cette thèse examine la recherche opérationnelle menée par le Corps canadien pendant la Première Guerre mondiale. Elle remet en question l'argument présenté par la plupart des historiens de la recherche opérationnelle, qui soutiennent que la discipline a vu le jour avec le Comité Tizard de 1935 et et s'est concrétisée pendant la Seconde Guerre mondiale. Cette thèse s'appuie sur l'enquête initiale menée par les chercheurs J.S. Finan et W.J. Hurley dans un article publié en 1997 et constatent que trois états-majors spécialisés du quartier général du Corps canadien – le bureau d'état-major de la contrebatterie, le Service du gaz du Corps canadien et le Corps des mitrailleurs canadiens – ont mené des recherches opérationnelles avec plus ou moins de rigueur. Aucun de ces états-majors n'a jamais utilisé le terme « recherche opérationnelle » pour décrire ses études scientifiques. Cependant, ils en étaient sans aucun doute les praticiens par leurs innovations, leurs essais, leur expérimentation et leur diffusion des connaissances – les quatre piliers de la discipline. Les artilleurs, les officiers de gaz et les mitrailleurs ont appliqué la science à leurs systèmes d'armes respectives et, ce faisant, les ont rendus aussi efficaces et efficients que possible. Et ils ont partagé les meilleures pratiques avec d'autres formations du Corps expéditionnaire britannique. Grâce à leurs études, le Corps canadien a protégé ses soldats des pires effets des armes chimiques et a utilisé du gaz, des barrages de mitrailleuses et des tirs de contre-batterie pour attirer l'armée allemande et frapper leurs systèmes les plus importants. Plusieurs des études menées par ces officiers d'état-major ont été reprises par dans des enquêtes similaires menées par la Section de recherche opérationnelle n° 2 pendant la Seconde Guerre mondiale. Par conséquent, cette étude offre une nouvelle interprétation de l'adaptation à la technologie, de l'approche scientifique des opérations et de l'apprentissage au sein du Corps canadien pendant la Première Guerre mondiale.

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List of Abbreviations

ASF	Fire order sent when the battery is firing for effect and the observer wishes to range the guns afresh
BEF	British Expeditionary Force
CA	Chemical Advisor
CAMC	Canadian Army Medical Corps
CB	Counter Battery
CBG	Counter-Battery Group
CBO	Counter-Battery Staff Office
CBSO	Counter-Battery Staff Officer
CCGS	Canadian Corps Gas Services
CCHA	Commander Canadian Corps Heavy Artillery
CDA	Canadian Divisional Artillery
CEF	Canadian Expeditionary Force
CFA	Canadian Field Artillery
CHAG	Canadian Heavy Artillery Group
CHB	Canadian Heavy Battery
CMGC	Canadian Machine Gun Corps
CWM	Canadian War Museum
DA	Divisional Artillery
DGO	Divisional Gas Officer
DND	Department of National Defence
FAT	Field Artillery Training
FOO	Forward Observation Officer
FSC	Field Survey Company
FSR	Field Service Regulations
GHQ	General Headquarters
GOC	General Officer Commanding
GOC RA	General Officer Commanding Royal Artillery
HAG	Heavy Artillery Group
HE	High Explosive
LAC	Library and Archives Canada
LOC	Line of Communication
MPI	Mean Point of Impact
OC	Officer Commanding
OMFC	Overseas Military Forces of Canada
ORS	Operational Research Section
RA	Royal Artillery
RAF	Royal Air Force
RE	Royal Engineers
RFC	Royal Flying Corps
RR	Ranging Rounds Fired
RRO	Ranging Rounds Observed
SBR	Small Box Respirator
SS	Stationery Service
TNA	The National Archives, Kew
WD	War Diary

Introduction

In a postwar interview, General Andrew G.L. McNaughton recalled that "1917 was a year of application of engineering and science to war, to the technique of war, to battle…. [I]f we were going to survive, if we were going to win the war, we just had to do these things."[1] McNaughton had served as the first counter-battery staff officer (CBSO) in the Canadian Corps and had proved himself an authority on innovation in gunnery methods and artillery survey equipment during the First World War. McNaughton and the staff of the counter-battery staff office (CBO) did vital work. Counter-battery fire – locating and neutralizing the German guns before the infantry went over the top – significantly contributed to the success of the Canadian Corps in the battles of 1917 and 1918. Necessity is the mother of invention, and few conflicts have spurred such radical technological developments in such a short period. A gunner from the Napoleonic Wars would have understood the artillery tactics and methods of 1914, while a present-day gunner would be familiar with techniques and procedures that McNaughton and his staff developed and perfected by applying science to warfighting.

Innovation, however, is meaningless for armies without a quantitative methodology to scrutinize the effectiveness and usefulness of inventions through a series of trials and experiments. If successful, officers had to share the innovation and any lessons learned during the trialling and experimentation with others. This methodology is now known as operational research. In a 1997 article published in *The Journal of the Operational Research Society*, J.S. Finan and W.J. Hurley write, "operational research has its roots in World War I with McNaughton and his counter-battery research group at Vimy."[2] Finan and Hurley's argument challenges the claims made by most historians of operational research, who contend that the origin of the discipline is the 1935 Tizard Committee, which sought to develop a radar-based air defence system for Britain.[3] Some historians have cited forerunners to operational research but downplay their lasting impact. For instance, historian Maurice Kirby acknowledges the importance of the work done by McNaughton and his staff. However, he writes, "Whilst their studies may be viewed in retrospect as employing analytical skills akin to operational research, they did not result in the sustained and conscious use of scientific techniques in the planning and execution of military operations."[4] Semantics also complicate scholarship on the origins of operational research since the term "operational research" did not enter the military lexicon until the 1930s. Still, the consensus amongst historians is that operational research began during the interwar years.

In two-plus decades since the publication of the Finan and Hurley article, the historiography of both the Canadian Corps and operational research has significantly developed. In addition to the official history, several historians have published monographs on the Canadian Expeditionary Force (CEF) during the First World War.[5] And now, nearly every major battle that the corps fought has been the subject of a

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[1] Library and Archives Canada (LAC), MG30-E133, General Andrew George Latta McNaughton Fonds (McNaughton Papers), Vol. 358, J.A. Swettenham, "Transcripts of Tapes of General McNaughton's Recollections of the First World War (Flanders Fields Transcripts)," Tape 2, 5-6, 17 January 1963.
[2] J.S. Finan and W.J. Hurley, "McNaughton and Canadian Operational Research at Vimy," *The Journal of the Operational Research Society*, Vol. 48, no. 1 (January 1997): 14.
[3] Terry Copp, "Scientists and the Art of War: Operational Research in 21 Army Group," *The RUSI Journal* Vol. 136, no. 4 (Winter 1991): 65; Maurice W. Kirby, *Operational Research in War and Peace: The British Experience from the 1930s to 1970* (London: Imperial College Press, 2003), 1; and Joseph F. McCloskey, "The Beginnings of Operations Research: 1934-1941," *Operations Research* Vol. 35, no. 1 (January – February 1987): 143.
[4] Kirby, *Operational Research in War and Peace*, 42.
[5] G.W.L. Nicholson, *Official History of the Canadian Army in the First World War: Canadian Expeditionary Force, 1914-1919* (Ottawa: Queen's Printer and Controller of Stationery, 1962). Histories of the Canadian Corps include: Desmond Morton, *When Your Number's Up: The Canadian Soldier in the First World War* (Toronto: Random House of Canada, 1993); Tim Cook, *At the Sharp End: Canadians Fighting the Great War 1914-1916, Volume One*

book-length study.[6] These scholars have disproved that the pluck and non-conventional approaches of the corps' non-regular soldiers made it successful.[7] Historian Douglas Delaney argues that the prewar efforts of the War Office to assign British officers to the armies of the Dominions and standardize staff training and formation structures enabled the assembly of an interoperable imperial army when the war began in 1914.[8] Not only have these works improved our understanding of the operational effectiveness of the Canadian Corps, they have also placed the formation in the context of the wider British Expeditionary Force (BEF) that fought on the Western Front.

Pertinent to this study, historians have also examined how the Canadian Corps used new technology, artillery, gas, and machine guns.[9] Crucially, these studies examine people, as well as tactical methods and weapon systems. The best systems and kit cannot make up for dumb soldiers. In *Surviving Trench Warfare: Technology and the Canadian Corps, 1914-1918*, Bill Rawling writes, "Technology does not evolve or change by itself but requires those who invent and those who adapt."[10] G.W.L. Nicholson expresses a similar view in the official history of The Royal Regiment of Canadian Artillery: "Canadian gunners would make their contribution, and not least in the application of scientific principles to reach the desired solutions."[11] Nicholson's volume remains the authoritative study of the Canadian artillery in the Great War. He provides a brief overview of the counter-battery developments in the Canadian Corps. For the more significant battles, he includes a brief one-or-two-sentence assessment of the effectiveness of counter-battery fire. Nicholson notes that the Canadian Corps excelled at counter-battery work due to "the receptiveness of its staff officers to new ideas and their willingness to *try* them out."[12] And Cook partially attributes the success of the Canadian artillery during the Battle of Vimy Ridge (9-12 April 1917) to "operational analysis."[13]

The reputation of the BEF has also undergone rehabilitation in the historiography. Most First World War historians agree that the BEF was not a case of "lions led by donkeys" but rather an

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(Toronto: Penguin Canada, 2007); and Tim Cook, *Shock Troops: Canadians Fighting the Great War, 1917-1918, Volume Two* (Toronto: Penguin Canada, 2008).

[6] Andrew Iarocci, *Shoestring Soldiers: The 1st Canadian Division at War, 1914-1915* (Toronto, Buffalo, and London: University of Toronto Press, 2008); William F. Stewart, *Canadians on the Somme, 1916: The Neglected Campaign* (Solihull: Helion & Company Limited, 2017); Geoffrey Hayes, Andrew Iarocci, and Mike Bechthold, eds., *Vimy Ridge: A Canadian Reassessment* (Waterloo: Wilfred Laurier University Press, 2007); Douglas E. Delaney and Serge Marc Durflinger, eds., *Capturing Hill 70: Canada's Forgotten Battle of the First World War* (Vancouver and Toronto: UBC Press, 2016); Shane B. Schreiber, *Shock Army of the British Empire: The Canadian Corps in the Last 100 Days of the Great War* (St. Catherine's: Vanwell Publishing Limited, 2004); and J.L. Granatstein, *The Greatest Victory: Canada's One Hundred Days, 1918* (Oxford: Oxford University Press, 2014).

[7] Pierre Berton and Ted Barris have propagated the Canadian "super-soldiers" myth. Pierre Berton, *Vimy* (Toronto: McClelland and Stewart, 1986); and Ted Barris, *Victory at Vimy: Canada Comes of Age, April 9-12, 1917* (Toronto: Thomas Allen, 2007).

[8] Douglas E. Delaney, *The Imperial Army Project: Britain and the Land Forces of the Dominions and India, 1902-1945* (Oxford: Oxford University Press, 2017).

[9] Bill Rawling, *Surviving Trench Warfare: Technology and the Canadian Corps, 1914-1918* (Toronto, Buffalo, and London: University of Toronto Press, 1992); G.W.L. Nicholson, *The Gunners of Canada: The History of the Royal Regiment of Canadian Artillery, Volume I, 1534-1919* (Toronto and Montreal: McClelland and Stewart Limited, 1967); Tim Cook, *No Place to Run: The Canadian Corps and Gas Warfare in the First World War* (Vancouver and Toronto: UBC Press, 1999); and G.S. Grafton, *The Canadian "Emma Gees:" A History of the Canadian Machine Gun Corps* (London: Hunter Printing Company, 1938).

[10] Rawling, *Surviving Trench Warfare*, 223.

[11] Nicholson, *The Gunners of Canada*, 214.

[12] Ibid, 315n1. Emphasis added by the author.

[13] Tim Cook, "The Gunners at Vimy: 'We are Hammering Fritz to Pieces,'" in *Vimy Ridge: A Canadian Reassessment*, eds., Geoffrey Hayes, Andrew Iarocci, and Mike Bechtold (Waterloo: Wilfred Laurier University Press, 2007), 120.

organization that did the best it could by adapting and learning how to fight against a first-class enemy.[14] Some commanders did not embrace new technology and methods, but most did.[15] Arguments that a dichotomy existed in the officer corps between "the traditional gentlemanly ideal and the technical, functionally competent, professional ideal"[16] are not borne out by an examination of how the BEF learned, innovated, and adapted. In *Learning to Fight: Military Innovation and Change in the British Army, 1914-1918*, Aimée Fox states "through a combination of its pre-war ethos and increased fluidity in wartime, the army displayed organisational and cultural flexibility, promoting informal learning and encouraging individuals to innovate."[17] Her work demonstrates clearly that the BEF was a learning organization. Indeed, Major C.H. Foulkes, a gas pioneer in the Royal Engineers, writes, "Throughout the war I found officers of high-rank almost too receptive of novel proposals, especially when they were based on anything mysterious or scientific."[18] The BEF reached far and wide into British industry and academic communities to find subject matter experts, whose expertise they could exploit.

The Canadian Corps did not have a monopoly on innovation. The corps benefitted from the technical developments of other formations in the BEF and the French Army. Canadian gunners benefitted from the technical developments that occurred in the British artillery, adopting new technology and adapting their artillery staff structure.[19] Historian Albert Palazzo argues that the formation of "a centralised staff of artillery personnel dedicated to the suppression of the enemy's batteries through the analysis and tactical application of intelligence" in each corps headquarters enabled the British to win the counter-battery fight.[20] The formation of the CBO "was a reflection of the vibrancy of British experimentation and their determination to find solutions to the stalemate on the Western Front."[21]

The Canadian Corps Gas Services (CCGS) and Canadian Machine Gun Corps (CMGC) also profited from the work and ideas of their British peers.[22] In *Chemical Soldiers: British Gas Warfare in World War I*, Donald Richter makes several references to the operational research – innovation, trialling, experimentation, and dissemination – done by the officers of the Royal Engineers Special Brigade yet he does not refer to this work as operational research.[23] British tactical and technical developments

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[14] Leon Wolff and Alan Clark are amongst the greatest critics of the supposedly incompetent leadership of the BEF. Leon Wolff, *In Flanders Fields: The 1917 Campaign* (Harmondsworth: Penguin Books, 1958); and Alan Clark, *The Donkeys* (London: Pimlico, 1961).

[15] Studies of British generalship on the Western Front include: Simon Robbins, *British Generalship on the Western Front, 1914-18: Defeat into Victory* (London and New York: Routledge, 2005); and Andy Simpson, *Directing Operations: The British Corps Command on the Western Front, 1914-18* (Stroud: Spellmount, 2006).

[16] Tim Travers, *The Killing Ground: The British Army, the Western Front and the Emergence of Modern Warfare, 1900-1918* (Barnsley: Pen & Sword Military Classics, 2003), 5.

[17] Aimée Fox, *Learning to Fight: Military Innovation and Change in the British Army, 1914-1918* (Cambridge: Cambridge University Press, 2018), 14.

[18] C.H. Foulkes, *"Gas!" The Story of the Special Brigade RE* (Edinburgh and London: Blackwood, 1934), 102.

[19] Jonathon Bailey, "British Artillery in the Great War," in *British Fighting Methods in the Great* War, ed., Paddy Griffith (London and Portland: Frank Cass, 1996), 23-49; Shelford Bidwell and Dominick Graham, *Fire-Power: British Army Weapons and Theories of War, 1904-1945* (Barnsley: Pen & Sword Military Classics, 1982); Martin Farndale, *History of the Royal Regiment of Artillery: Western Front, 1914-18* (Woolwich: The Royal Artillery Institution, 1986); Sanders Marble, *British Artillery on the Western Front in the First World War: "The Infantry cannot do with a gun less"* (London and New York: Routledge, 2013); and Paul Strong and Sanders Marble, *Artillery in the Great War* (Barnsley: Pen & Sword Military, 2013).

[20] Albert A. Palazzo, "The British Army's Counter-Battery Staff Office and Control of the Enemy in World War I," *The Journal of Military History* Vol. 63, no. 1 (January 1999): 57.

[21] Ibid, 74.

[22] Albert Palazzo, *Seeking Victory on the Western Front: The British Army and Chemical Warfare in World War I* (Lincoln and London: University of Nebraska Press, 2000); and Donald Richter, *Chemical Soldiers: British Gas Warfare in World War I* (Lawrence: University Press of Kansas, 1992).

[23] Richter, *Chemical Soldiers*, 10, 13, 16, 18, 92, 148-158, 183, 207-208, 220.

invariably impacted the CEF, and the Dominion soldiers became proficient through the same learning process as the British Army. Paddy Griffith argues, "This revolution in tactics was applied to the whole BEF rather than just to a portion of it and, contrary to much recent transatlantic disbelief and denigration, was routinely applied in practice."[24]

Personalities are prominent in this examination. Innovators, patrons, and detractors all factor into an assessment of operational research and the Canadian Corps. While the effectiveness of McNaughton as the commander of the First Canadian Army during the Second World War remains contentious, every assessment of his tenure as the CBSO of the Canadian Corps is favourable.[25] Historian John Rickard notes, "Counter-battery work demanded precision, and McNaughton's scientifically attuned mind readily worked the problem. In this he was aided by a newly formed operational research team (predating such efforts in the Second World War)."[26] Historians also credit the innovative work done by Brigadier-General Raymond Brutinel with the CMGC.[27] Yves Tremblay writes that Brutinel "was a technical and organization innovator and an unrivalled experimentalist."[28]

Innovators needed the support of the chain of command. Support stemmed from the highest ranks of the BEF. In his biography of Field Marshal Sir Douglas Haig, the commander-in-chief of the BEF, Gary Sheffield writes that Haig had a "wide-ranging grasp of all aspects of his command, and a willingness to back 'subject-matter experts.'"[29] Haig was no technophobe. Indeed, his most significant fault was not that he had no faith in technology but that, at times, he had too much faith in it.[30] The leadership of the Canadian Corps also embraced technological innovation. Several historians have studied the corps commanders and staff, and some have completed an initial inquiry into the divisional and brigade levels.[31] None, however, examine at length how these commanders supported innovation within their formations. Lieutenant-General Sir Julian Byng and Lieutenant-General Sir Arthur Currie, two of the three commanders of the Canadian Corps, are the subject of book-length studies.[32] Byng took great

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[24] Paddy Griffith, *Battle Tactics of the Western Front: The British Army's Art of Attack, 1916-18* (New Haven and London: Yale University Press, 1994), 194.

[25] John Swettenham, *McNaughton: Volume 1, 1887-1939* (Toronto: The Ryerson Press, 1968); Paul Dickson, "Leadership and Innovation: Andrew McNaughton and the Counter-Battery Staff Office," in *Great War Commands: Historical Perspectives on Canadian Army Leadership*, ed., Andrew B. Godefroy (Kingston: Canadian Defence Academy Press, 2010), 145-166; and John Nelson Rickard, *The Politics of Command: Lieutenant-General A.G.L. McNaughton and the Canadian Army, 1939-1943* (Toronto, Buffalo, and London: University of Toronto Press, 2010).

[26] Rickard, *The Politics of Command*, 17.

[27] Cameron Pulsifer, "Canada's First Armoured Unit: Raymond Brutinel and the Canadian Motor Machine Gun Brigades of the First World War," *Canadian Military History* Vol. 10, no. 1 (2001): 44-57; and Yves Tremblay, "Brutinel: A Unique Kind of Leadership," in *Warrior Chiefs: Perspectives on Senior Canadian Military Leaders*, eds., Bernd Horn and Stephen Harris (Toronto and Oxford: Dundurn Press, 2001), 57-70.

[28] Tremblay, "Brutinel," 59

[29] Gary Sheffield, *The Chief: Douglas Haig and the British Army* (London: Aurum, 2011), 102.

[30] Ibid, 62.

[31] Studies of commanders and staffs at various formation levels in the Canadian Expeditionary Force include: Douglas E. Delaney, "Mentoring the Canadian Corps: Imperial Officers and the Canadian Expeditionary Force, 1914-1918," *The Journal of Military History* Vol. 77, no. 3 (July 2013): 931-953; William F. Stewart, *The Embattled General: Sir Richard Turner and the First World War* (Montreal and Kingston: McGill-Queen's University Press, 2015); and Ian McCulloch, "'Batty Mac:' Portrait of a Brigade Commander of the Great War, 1915-1917," *Canadian Military History* Vol. 7, no. 4 (Autumn 1998): 11-28.

[32] Jeffrey Williams, *Byng of Vimy: General and Governor General* (London: Leo Cooper, 1983); Dan Dancocks, *Sir Arthur Currie: A Biography* (Toronto: Methuen, 1985); A.M.J. Hyatt, *General Sir Arthur Currie: A Military Biography* (Toronto, Buffalo, and London: University of Toronto Press, 1987); and Tim Cook, *The Madman and the Butcher: The Sensational Wars of Sam Hughes and General Arthur Currie* (Toronto: Penguin Canada, 2010).

interest in the work of McNaughton and frequently visited the CBO.[33] Support for innovation continued while Currie commanded the corps. Tim Cook notes that Currie "had an open and welcoming headquarters, where officers were encouraged to speak up, share ideas, and question assumptions."[34]

Scholars have also examined military operational research, but they have done so in an almost exclusively Second World War context. This approach is problematic since soldiers had conducted primitive forms of operational research well before the 1939-1945 War. For instance, as a junior officer at *l'École royale d'artillerie d'Auxonne* in August 1788, Napoleon experimented with firing explosive shells from cannons instead of mortars.[35] He then presented his findings in a clear, detailed memorandum. In addition to the Kirby monograph, historians have examined the impact of operational research on the Allied strategic bombing offensive and the operations of the 21st Army Group (of which First Canadian Army formed a part) during the Northwest Europe campaign, to name just two.[36] However, no one has further examined the Finan-Hurley argument that operational research had its genesis in the First World War and that it was practiced diligently by the Canadian Corps, among other BEF formations. This thesis fills this gap in the historiography of operational research and the Canadian Corps of the First World War. In doing so, it will answer: did the Canadian Corps of the First World War conduct operational research as we now understand it?

Before we can answer if the Canadian Corps conducted operational research in support of their operations, we must first define what we mean by operational research. Operational research is a branch of managerial science defined by the United Kingdom's Operational Research Society as:

> [T]he application of the methods of science to complex problems arising in the direction and management of large systems of men, machines, materials, and money in industry, business and defence. The distinctive approach is to develop a scientific model of the system, incorporating measurements of factors such as chance and risk, with which to predict and compare the outcomes of alternative decisions, strategies or controls. The purpose is to help management determine its policy and actions scientifically.[37]

Operational research supports decision-making with science. The discipline adheres to the scientific method in that hypotheses examined through operational research are testable, replicable, and observable. While operational research does not necessarily lead to better decisions, it does, as one operational research practitioner noted, improve "the degree of confidence that can be placed in the correctness of the result."[38] Operational research methodology is quantitatively based; however, the discipline of operational research does not necessarily involve complicated mathematics. In a military context, operational research provides commanders and staffs with a method to measure performance and effectiveness. These measures

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[33] Williams, *Byng of Vimy*, 146.
[34] Cook, *The Madman and the Butcher*, 196.
[35] Andrew Roberts, *Napoleon the Great* (London: Penguin Books, 2014), 25.
[36] Studies of operational research during the Second World War include: Copp, "Scientists and the Art of War ;" "Operational Research and 21 Army Group," *Canadian Military History* Vol. 3, no. 1 (1994): 71-84; "Counter-Mortar Operational Research in 21 Army Group," *Canadian Military History* Vol. 3, no. 2 (1994): 45-52; Joseph F. McCloskey, "British Operational Research in World War II," *Operations Research* Vol. 35, no. 3 (May – June 1987): 453-470; Jason Ridler, "Leadership and Science at War: Colonel Omond Solandt and the British Army Operational Research Group, 1943-1945," in *Canada and the Second World War: Essays in Honour of Terry Copp*, eds., Geoffrey Hayes, Mike Bechthold, and Matt Symes (Waterloo: Wilfred Laurier University Press, 2012), 173-198; and Randall T. Wakelam, *The Science of Bombing: Operational Research in RAF Bomber Command* (Toronto, Buffalo, and London: University of Toronto Press, 2009).
[37] Kirby, *Operational Research in War and Peace*, 3.
[38] Quoted in ibid, 25.

inform them if they are doing the right things and doing the right things well. Commanders seek to employ their forces as efficiently and effectively as possible, and operational research provides commanders and their staffs quantitative tools to measure how well they are using their forces and how well their forces are performing.

In terms of method, this study will examine four indicators of operational research in the Canadian Corps: innovation, trials, experimentation, and dissemination of findings. Innovation refers to the development of a new method, idea, equipment, or weapon. Officers and scientists trialled these innovations – to varying degrees of rigour – before implementation or fielding for experimentation. Experiments had to occur on the battlefield and required rigorous after-action review and analysis. This was the most critical step in the operational research process and produced "lessons learned." Officers then shared these lessons with other formations in the BEF. The battlefield is a problematic laboratory to conduct trialling and experimentation. The experimenter can rarely control variables, and the enemy can always modify its tactics, techniques, and procedures, which starts the process over at the beginning. Officers disseminated knowledge through several means ranging from casual conversation in a mess to the publication of BEF-wide pamphlets. Staff officers needed to disseminate these findings to avoid duplicated effort and the costly relearning of lessons. This dynamic process enabled the BEF to "outlearn" and eventually outfight the German Army.

The sources required to examine these indicators are extensive. To start, I will consult the personal papers of those involved with operational research and others who served on the artillery, machine gun, and chemical warfare staffs. Included amongst these are Currie, Brutinel, McNaughton, Major-General E.W.B. Morrison, and Lieutenant-Colonels H.D.G. Crerar and Alan F. Brooke. I will also examine official records, including reports, war diaries, doctrinal publications, manuals, and pamphlets. Examining these sources will allow for a reasonable assessment of how the staff of the Canadian Corps used operational research to conduct counter-battery fire, protect its soldiers from the effects of gas, use gas offensively and defensively against the Germans, and supplement fire plans with machine guns firing in an indirect role.

This thesis will also raise questions about assumptions and oft-quoted statistics that appear in the literature on the Canadian Corps. Many historians, for example, mention the proficiency of the corps at counter-battery operations. Morrison, the chief gunner of the Canadian Corps, remarked after the attack on Vimy Ridge, "There was not a battery position that had not been discovered and successfully dealt with."[39] McNaughton's biographer claimed that the counter-battery programme neutralized eighty-three percent, the oft-cited statistic, of the German guns before the assault.[40] However, this statistic seems suspect since No. 2 Operational Research Section (ORS) made more subdued comments on the effectiveness of the counter-battery fire conducted by the artillery in 21st Army Group.[41] This thesis will also scrutinize the effectiveness of the Canadian Corps at protecting its soldiers from gas, using gas against the enemy, and firing machine guns in an indirect role. This study will not examine all cases of operational research that were conducted in the BEF and is mostly limited to the Canadian Corps. Officers in other British corps used a form of operational research to improve the effectiveness of artillery for wire cutting, test new munitions, and employ flamethrowers on the battlefield. The Canadian Corps did not perform these experiments, so they are beyond the scope of this study.

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[39] Major-General Sir Edward Morrison, *Morrison: The Long-Lost Memoir of Canada's Artillery Commander in the Great War*, ed., Susan Raby-Dunne (Victoria, Vancouver, and Calgary: Heritage, 2017), 124.
[40] Swettenham, *McNaughton*, 90.
[41] "Report No. 16, Ground Support in Assault on Boulogne," in Terry Copp, ed., *Montgomery' Scientists: Operational Research in Northwest Europe – The Work of No. 2 Operational Research Section with 21 Army Group, June 1944 to July 1945* (Waterloo: Laurier Centre for Military Strategic and Disarmament Studies, 2000), 332-336.

The central finding of this thesis is that while the staff of the Canadian Corps never used the term "operational research," they were undoubtedly practitioners of the discipline. The innovation, trials, experimentation, and dissemination of results done by the Canadian Corps CBO, the CMGC, and the CCGS between 1915 and 1918 were the harbingers of the operational research conducted by No. 2 ORS in the 21st Army Group during the Northwest Europe campaign of the Second World War.[42] Several of the Great War operational researchers went on to fill key command positions in the Second World War and ensure that the lessons learned were not lost. Innovation did not only come from within the ranks of the CEF. The corps sought out expertise from officers in other formations and civilians with knowledge in a field that was relevant to military operations. Operational research would have had a minimal impact had the chain of command not supported the work, and if the knowledge and lessons learned had not been compiled and disseminated to the other formations that comprised the BEF. These lines of inquiry form the chapters of this thesis. How did the Canadian Corps use operational research to conduct counter-battery fire? How did operational research enable the corps to use gas and machine guns to shape the battlefield? What is the legacy of operational research in the Canadian Corps? Studying how the corps embraced operational research informs us of much more than how senior commanders and staff thought about the influence of science on warfighting. It demonstrates how an army was able to exploit the intellectual capacity of both its personnel and its civilian population to learn, adapt, and eventually outfight their German foes on the battlefield.[43]

[42] Terry Copp has edited a volume that contains all the reports prepared by No. 2 ORS during the campaign. See Copp, ed., *Montgomery' Scientists*.

[43] Aimée Fox has examined the British Army's use of civilian expertise in some depth, particularly for the development of its logistical systems. See Fox, *Learning to Fight*, 164-203.

Chapter 1 – Operational Research and the Artillery Duel

Field Marshal Sir Douglas Haig did not mince his words when he described the importance of the innovations in gunnery and counter-battery procedures that had occurred in the BEF.

> Four years of *scientific* warfare have seen a consistent and progressive development in the power and influence of artillery, both in the actual infantry battle and in all the stages which lead up to it. Despite the handicap under which we started the war, British Artillery has played a large part in this development, and of late has dominated the enemy's artillery to an ever increasing degree.... The influence of this fact upon the morale, both of our own and the enemy's troops, could hardly be exaggerated.[44]

The infantrymen in Haig's army depended on the artillerymen to neutralize the enemy's guns before they launched their attacks. Artillery, not machine guns, were the real killers on the battlefield, accounting for approximately sixty percent of all battlefield casualties in the First World War.[45] If the artillery failed to silence the German guns, the infantryman would be subjected to withering shellfire while advancing through no man's land. At best, attacks launched under these conditions cost the assaulting battalions dearly as the soldiers seized their objectives. At worst, these attacks failed utterly and only caused high casualties. BEF gunners knew they had to silence the German guns, but how?

Andrew McNaughton and the counter-battery staff used operational research to neutralize the German artillery. After the Battle of the Somme (1 July – 18 November 1916), the Canadian Corps rarely attacked with less than half of the German guns suppressed. Operational research also helped the staff assess the effectiveness of their methods. Through innovation, trialling, experimentation, and dissemination, the CBSO and his officers developed the necessary technology, staff structure, and methods. They benefited from the innovations of other British and French officers as well as civilian scientists, and they enjoyed the support of the senior commanders and staff of the Canadian Corps. Many heavy guns with a robust quantity of ammunition also helped. However, McNaughton and his team worked in a doctrinal vacuum and faced certain constraints, from difficult terrain to the accelerating operational tempo of the corps. Despite these considerable challenges, the Canadian Corps had one of the most proficient CBO in the BEF. Operational research enabled McNaughton and his staff to form this proficient cell and enhance its effectiveness.

The British Army had not given much thought to counter-battery work before the First World War. The *Field Service Regulations* (*FSR*) of 1909 provided some general principles for the handling of artillery. The artillery supported "the other arms in breaking down hostile opposition … [by] establishing a superiority of fire over the enemy."[46] The *FSR* only mentions counter-battery fire as a possible task for howitzers and heavy artillery. *Field Artillery Training* (*FAT*) of 1914 furnished a bit more direction on counter-battery work.[47] During the opening phase of an attack, the artillery would "locate the enemy's batteries and, by subduing the fire of those in action, to support the infantry."[48] *FAT* also laid the groundwork for counter-battery work by suggesting methods to locate the enemy guns and by providing instruction on the procedure to suppress hostile batteries. However, *FAT* did not explicitly assign responsibility for counter-battery work to an officer or staff. Artillerymen should only engage hostile

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[44] J.H. Boraston, ed., *Sir Douglas Haig's Despatches, December 1915 – April 1919* (London and Toronto: J.M. Dent & Sons Ltd., 1919), 300. Emphasis added by the author.
[45] T.J. Mitchell, *History of the Great War: Medical Services, Casualties and Medical Statistics of the Great War* (London: His Majesty's Stationery Office, 1931), 40.
[46] General Staff, War Office, *Field Service Regulations, Part I: Operations, 1909* (London: His Majesty's Stationery Office, 1912), 15-16.
[47] General Staff, War Office, *Field Artillery Training, 1914* (London: His Majesty's Stationery Office, 1914).
[48] Ibid, 246.

batteries if they could observe them. "Unless the enemy's artillery by exposing itself offers an opportunity for its destruction, commensurate with the expenditure of ammunition involved, fire should be confined to those hostile batteries that can be located, which are impeding the infantry advance."[49] If the Germans sited their guns in defilade, the British artillery could not target them efficiently since few gunners besides those in the Royal Garrison Artillery understood how to engage targets with indirect fire. Hampered by this limited corporate knowledge, the Royal Artillery struggled to develop techniques for counter-battery during the early period of the war.

BEF gunners knew that they needed to suppress the German guns, but between 1914 and 1916, they lacked the tools to do it. Several factors hindered the effectiveness of the British artillery's counter-battery work: inadequate maps and survey, insufficient heavy guns, shortages of artillery ammunition, and no centralized counter-battery staff.[50] These shortcomings often resulted in unsatisfactory shoots. Consequently, when the infantry attacked, unharried German guns were still able to lay down deadly defensive fires. This scenario occurred at every significant British battle in 1915: Neuve Chapelle (10-13 March), Second Ypres (22 April – 25 May), Aubers Ridge (9 May), Festubert (15-25 May), and Loos (25 September – 8 October).[51] The infantry also pressured the artillery to prioritize fires on defensive positions and wire over counter-battery work. The *FSR* dictated that fires were to "be directed against what, for the time being, are the most important targets from the infantry point of view."[52] The gunners complied and, at Neuve Chappelle, for instance, one battery only had thirty-two shells allotted per day to suppress thirty-five German batteries.[53] Given the limited ability of the British artillery to conduct counter-battery, this was not an unreasonable decision. Still, the preference of the infantry for the artillery to focus on the "close" battle led gunners to focus their efforts on improving the pre-battle bombardment and the barrage that supported the infantry's advance – all at the expense of the deeper counter-battery battle. Consequently, when the BEF went to battle on the Somme, counter-battery procedures had evolved little from the battles of 1915.

But the Somme did mark a watershed moment for the BEF, particularly for the artillery. The seven-day preparatory bombardment had mixed results, as did the barrage fired on 1 July to support the infantry's advance.[54] After the campaign ended in November 1916, Major Alan F. Brooke, then Brigade Major Royal Artillery of the 18th (Eastern) Division, assessed the innovations that had occurred during the battle: "In the handling of artillery we had made great progress, we now had enough guns and ammunition to make it possible to obtain the massed effect of artillery fire. We had made great progress in the co-ordinated control of artillery."[55] However, he noted that the BEF still had yet to learn that "the main advantages to be derived from artillery fire was in its power of neutralising the hostile rifle, machine gun and artillery fire, as opposed to the destruction of trenches and obstacles."[56] As Brooke notes, the artillery still had much work to do. By the end of 1916, however, the BEF had enough shells and heavy

[49] Ibid, 247.
[50] King's College London, Liddell Hart Centre for Military Archives (LHCMA), Papers of Field Marshal Viscount Alanbrooke of Brookeborough (Alanbrooke Papers), 3/10, "'Evolution of artillery in the Great War, 1914-1918,' bound copy of offprints of articles by Brooke from the *Royal Artillery Journal*, Vols 51-53, based on his lectures to Senior Division, Staff College, Camberley (Evolution of Artillery in the Great War 1914-1918)," 364, 366, 372.
[51] Farndale, *History of the Royal Regiment of Artillery*, 90, 99, 106, 109,124; and Nicholson, *The Gunners of Canada*, 210, 231.
[52] War Office, *Field Service Regulations*, 135.
[53] Marble, *British Artillery on the Western Front in the First World War*, 75.
[54] Strong and Marble, *Artillery in the Great War*, 91-93.
[55] Brooke went on to become Field Marshal Viscount Alanbrooke and served as Chief of the Imperial General Staff during the Second World War. LHCMA, Alanbrooke Papers, 5/2/13, "Notes on My Life," 57, November – December 1916.
[56] Ibid.

guns.[57] Major-General J.F.N. Birch, Haig's chief gunner at General Headquarters (GHQ), shared several of Brooke's observations, and he issued direction for the BEF artillery to develop its counter-battery capabilities during the winter of 1916-1917.[58] Still, the British Army needed to field new technology and form an efficient targeting staff to execute counter-battery fire. Artillery staff needed to conduct operational research to win the artillery fight.

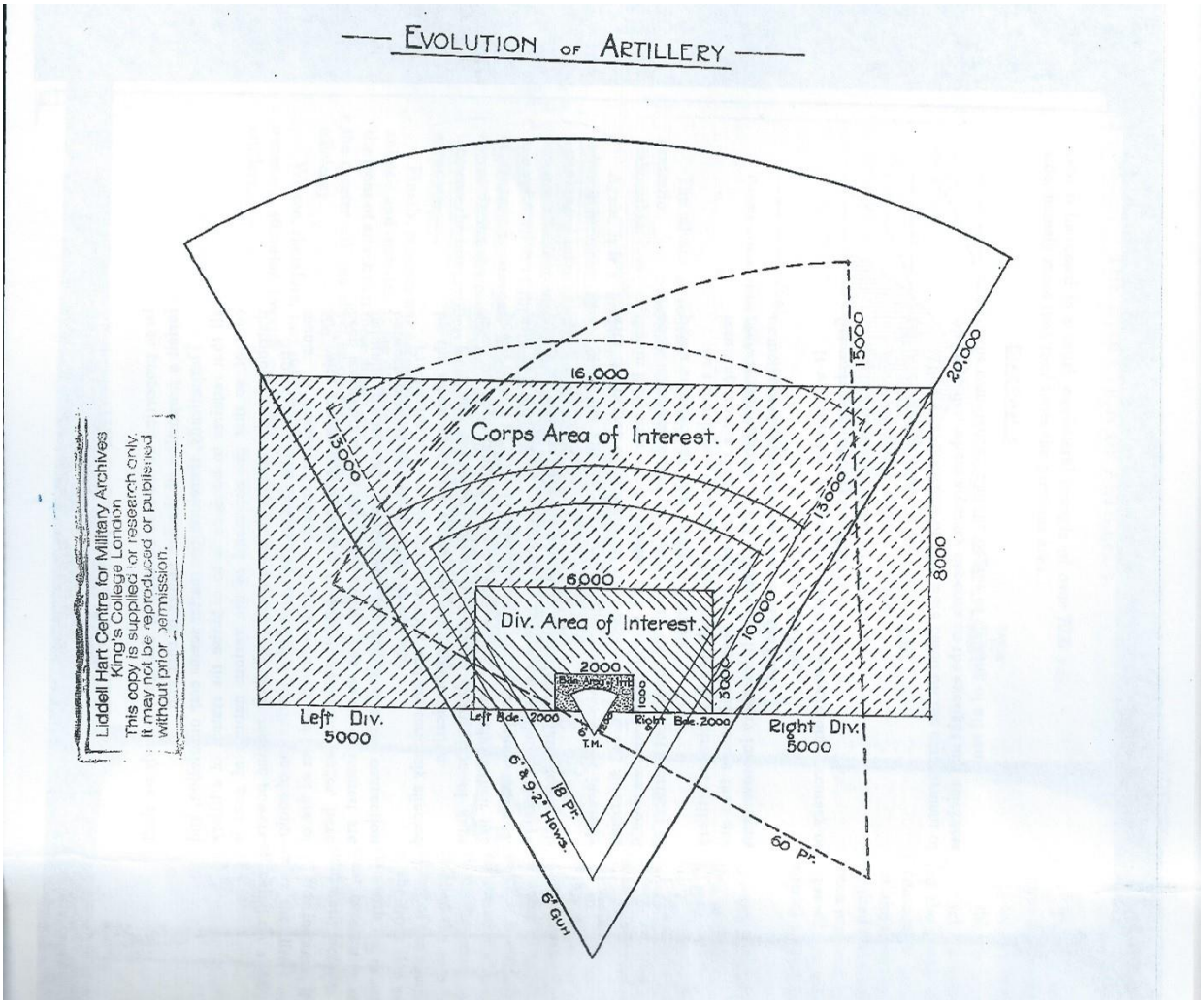

Figure 1.1 Distribution of Artillery Pieces to Formations in Accordance with Their Ranging Powers.
Source: LHCMA, Alanbrooke Papers, 3/10, "Evolution of Artillery in the Great War 1914-1918," insert 370-371.

The BEF opted to place the CBO in the corps headquarters. This decision had much to commend it. The corps had supplanted the division as the formation that planned and executed operations by 1916.[59] Corps controlled most of the Royal Artillery's heavy guns required for counter-battery and did not move between sectors of the front as frequently as divisions did (see figure 1.1). The size of the corps staff had drastically increased since 1914. The corps headquarters needed these additional staff officers to control the artillery, which had increased in strength from 504 pieces in August 1914 to 6,406 in November 1918,

[57] Farndale, *History of the Royal Regiment of Artillery*, 149.
[58] Ibid, 156.
[59] LHCMA, Alanbrooke Papers, 3/10, "Evolution of Artillery in the Great War 1914-1918," 373, 478; and Simpson, *Directing Operations*, 64.

with 2,204 heavy guns.[60] The staff working for the senior gunner in the corps, the General Officer Commanding Royal Artillery (GOC RA), expanded from just two officers in 1914 to eleven in 1918, with additional non-commissioned officers attached to the headquarters as clerks.[61] By 1918, the CBSO had a staff captain and two orderly officers responsible for counter-battery operations and another staff captain responsible for artillery intelligence (see figure 1.2).[62] The adjutant of each heavy artillery group acted as a liaison between the CBO and, most critically, provided battle damage assessment after each engagement.[63] The CBSO also controlled the corps survey section comprised of sappers and engineering officers, although the chief engineer in the corps still commanded this unit. By necessity, these staff acted as the ORS for the Canadian Corps artillery.

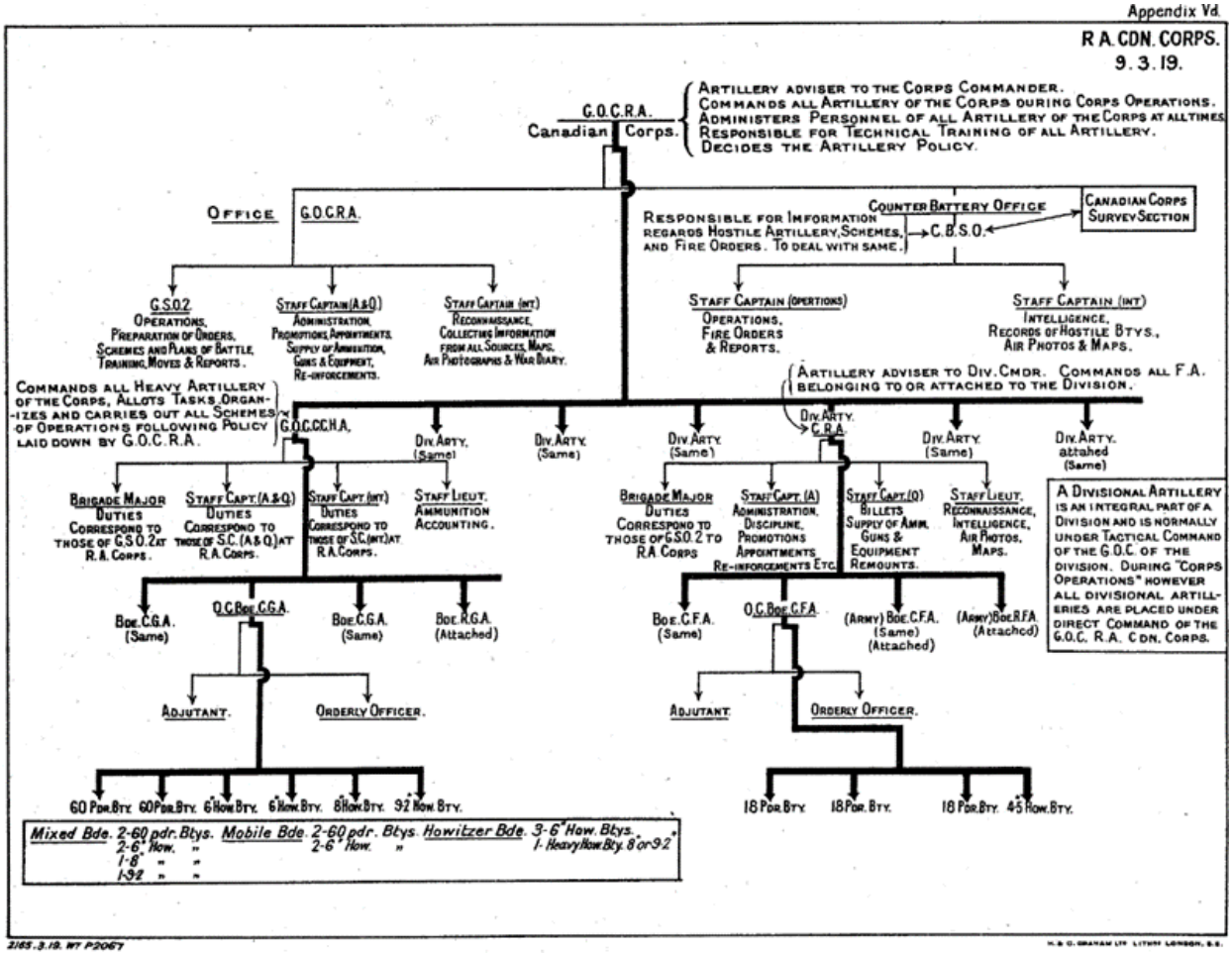

Figure 1.2 Organization and Staff Structure of the Canadian Corps Artillery, 1918
Source: Ministry Overseas Military Forces of Canada (OMFC), *Report of the Ministry Overseas Military Forces of Canada, 1918* (London: His Majesty's Stationery Office, 1919), insert page 240-241.

[60] Nicholson, *The Gunners of Canada*, 311.
[61] Simpson, *Directing Operations*, 231-235.
[62] LAC, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery, Vol. 3903, Folder 19, File 2, CBO, "Memoranda on the Organization of Counter-Battery Work in the Canadian Corps," 16, 20 May 1918.
[63] LAC, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery, Vol. 3903, Folder 19, File 3, CBO, C.B. 186/2, "Duties of Counter-Battery Adjutants with Heavy Artillery Groups," 1-2, 9 June 1918.

Major-General E.W.B. Morrison had already named McNaughton as CBSO when the Canadian Corps formed its CBO on 10 February 1917. With his hydroelectrical engineering background, McNaughton was well suited to this technical appointment.[64] The Canadian Corps also set him up for success by informing him of his new duties several weeks before the appointment became official. McNaughton expressed his satisfaction with his new role in a letter to his wife.

> For the first time in my soldiering life, I am out of the sound of the guns. Out of the sound I am, but very much in on the control of fire of our own. I think it is going to be a most interesting branch of the work with great possibilities for the *development* and *systematization* of the destruction of our friend the Hun.[65]

He understood the many characteristics of complex systems, and he could identify the strengths and weaknesses of the BEF artillery to address inefficiencies. McNaughton also applied this systematic approach to the enemy, which enabled the Canadian Corps to destroy or disrupt the enemy's artillery in the most expedient manner.

McNaughton's three principal assistants – the staff officer (operations), the orderly officer, and the staff officer (intelligence) – brought a combination of practical experience and administrative abilities that rounded out McNaughton's technical mind. Captain A.E.W. Nesbitt, a Royal Garrison Artillery officer on loan from the British Army, filled the staff captain (operations) appointment.[66] When Nesbitt sustained an injury on 3 November 1918, he was replaced by the able Lieutenant P.H. Skelton, a mechanical engineer in Montreal before he enlisted.[67] And, as his orderly officer, McNaughton brought his adjutant from the 11th (Howitzer) Brigade, Canadian Field Artillery, Captain L.P. Napier. Before the war, Napier had been a barrister, and his legal training no doubt impressed upon him the importance of research and meticulous record keeping.[68] Indeed McNaughton noted that Napier was "absolutely one hundred percent efficient."[69] Captain E.H. Davidson, another officer on loan from the British Army, worked as the intelligence officer in the CBO.[70] An injury had left him unfit for frontline duty, so he transferred to the Royal Flying Corps (RFC) and specialized in the analysis of aerial photographs. His older brother, Major-General Sir John Davidson, held senior staff appointments at GHQ, which McNaughton exploited to get information and support for his ideas.[71] The combined technical, practical, and administrative talent of the staff in the CBO set the conditions for the staff to quantitatively analyze the effectiveness of all facets of the counter-battery system of the Canadian Corps.

McNaughton identified four essentials of counter-battery work: control of enough guns and ammunition, intelligence, communications, and technical abilities.[72] The CBSO controlled the heavy guns and their ammunition, but he did not command them. The GOC RA did. McNaughton relied upon senior leaders in the Canadian Corps to get him the guns and ammunition that he needed for counter-battery

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[64] LAC, RG150, Accession 1992-93/166, Box 7142-18, Andrew George Latta McNaughton Personnel File.
[65] Quoted in Swettenham, *McNaughton*, 74. Emphasis added by the author.
[66] The National Archives, Kew (TNA), WO 372/14/196493, Medal Card of Andrew Edmundson Walsh Nesbitt; LAC, RG24, Department of National Defence, Vol. 447, Historical Section, General Staff, 54-21-1-203, "Officers of the British Forces Who Have Served with the OMFC during the 1914-1918 War," 6, 6 October 1927; and LAC, RG150, Vol. 473, "Officers Commanding Units – Headquarters Canadian Army Corps," n.d.
[67] LAC, RG150, Accession 1992-93/166, Box 8958-53, Philip Hanbury Skelton Personnel File.
[68] LAC, RG150, Accession 1992-93/166, Box 7233-23, Lennox Pelham Napier Personnel File.
[69] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 11, 9, 15 February 1963.
[70] TNA, WO 339/6574, Edward Humphrey Davidson Personnel File; and TNA, AIR 76/123/159, Edward Humphrey Davidson Personnel File.
[71] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 11, 14-15, 15 February 1963.
[72] A.G.L. McNaughton, "Counter-Battery Work," *Canadian Defence Quarterly* Vol. III, no. 4 (July 1926): 380.

work, which they almost always did.[73] Experimentation proved that destructive counter-battery shoots required the heavy guns controlled by the army, but the battles of 1916 had proved that guns and ammunition alone could not win the artillery fight.[74] They had to be used intelligently and with purpose.

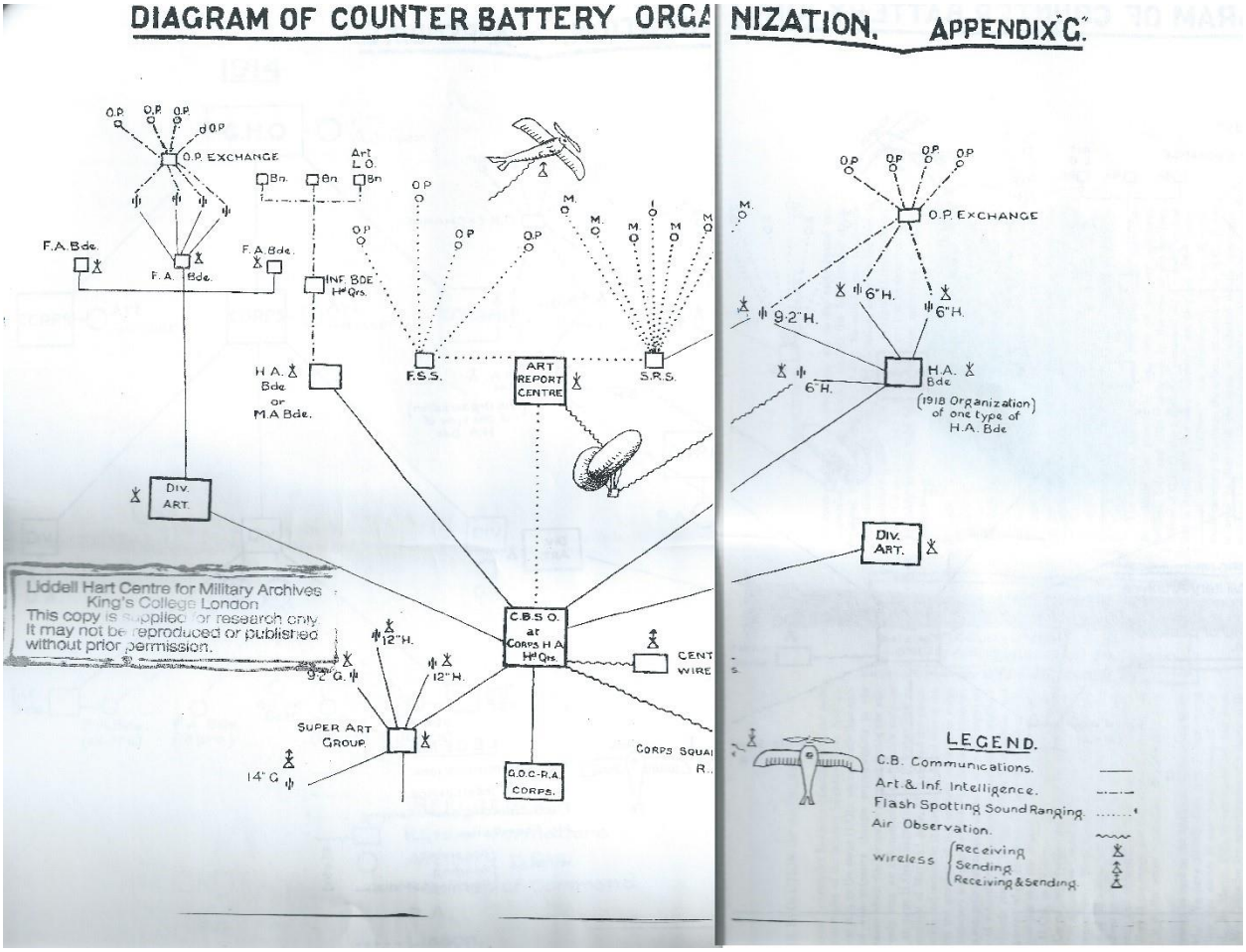

Figure 1.3 The BEF Counter-Battery System, 1918
Source: LHCMA, Alanbrooke Papers, 3/10, "Evolution of Artillery in the Great War 1914-1918," insert 386-387.

Through operational research, McNaughton sought to optimize the organization and equipment of the CBO (see figure 1.3). He described the intelligence system that existed in the Canadian Corps. "The people who had the information know where to pass it, how to coordinate their information … in time to be of some use."[75] The intelligence officer then needed to analyze these reports, catalogue them on the hostile battery list with a unique number, and plot them on the battle map to ensure accurate battle tracking. Not only did intelligence need to determine where the German artillery was, but intelligence also needed to inform the CBSO of their calibre, disposition, degree of protection, and arcs of fire.[76] Counter-battery work relied upon efficient communications between observers, the CBO, and the guns. It also required the staff to standardize its work with GHQ standards to ensure that reinforcing artillery

[73] LAC, MG30-E81, Major-General Sir Edward Whipple Bancroft Morrison Fonds (Morrison Papers), Vol. 2, Artillery Corps Notes and Pamphlets, "The Canadian Artillery in the Great War," 6-8, n.d.
[74] LAC, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery, Vol. 3903, Folder 20, File 2, First Army Headquarters, "Artillery Instruction No. 2 Employment of 12-inch and 15-inch Howitzers," 17 March 1917.
[75] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 2, 5, 17 January 1963.
[76] Nicholson, *The Gunners of Canada*, 313, 316.

could prosecute enemy batteries in accordance with the counter-battery programme. Technical abilities entailed the whole gamut of gunnery.[77] RFC air observers, sound-rangers, flash-spotters, and forward observation officers (FOO) needed to be able to determine the location and nature of enemy targets precisely and accurately. The artillery survey facilitated the observer's work by providing them with gridded maps.[78] The surveyors also placed all the guns on common fixation and orientation. The variations in barrel wear, ammunition, and meteorological conditions all needed to be accounted for as well. These all helped batteries conduct somewhat accurate, predicted fire.[79] By synchronizing the engagements of targets by fires with the manoeuvre of infantry and cavalry, surprise on the battlefield was again possible. Operational research could not get the Canadian Corps the guns or ammunition that it needed, but it did help the CBO perfect its intelligence system, communications, and technical abilities. The perfection of this system did more to win the counter-battery fight than any one technical development.

McNaughton and his team had their work cut out for them. However, they did not have to start from scratch, as some historians have claimed.[80] As part of the extensive learning that occurred during the winter of 1916-1917, GHQ promulgated *SS139/3 Artillery Notes No. 3 – Counter Battery Work*.[81] This pamphlet provided the rigour to counter-battery work that *FAT* lacked.

> Counter-battery work is not a matter of spasmodic effort, but is a continuous operation depending for success on accuracy of fire, continuity of plan, unremitting study and firm control. Its conduct along these lines will alone meet the end in view, namely the considerable if not total reduction at decisive moments of the volume of hostile artillery fire.[82]

SS139/3 delineated organization and command, detailed the allotment of artillery, and described the procedures to be followed to locate and record the positions of hostile batteries. As historian Aimée Fox writes, these notes "acted as an important means for collecting and disseminating specific knowledge."[83] The BEF never entirely centralized learning, which would have stifled innovation, and these pamphlets disseminated lessons learned amongst the formations on the Western Front and thereby minimized duplication of effort from multiple staffs working on the same product. Direction from GHQ also helped to standardize the counter-battery work that had been quite haphazard during the Somme.[84] Following the same procedures, speaking the same terms, and completing the same reports ensured interoperability between the corps in the BEF and greatly facilitated handovers. Army orders to their corps further

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[77] LHCMA, Alanbrooke Papers, 3/10, "Evolution of Artillery in the Great War 1914-1918," 37-51.
[78] On artillery survey, see Geographical Section, General Staff, War Office, *Report on Survey on the Western Front, 1914-1918* (London: His Majesty's Stationery Office, 1920), 84-138; John R. Innes, *Flash Spotters and Sound Rangers: How They Lived, Worked and Fought in the Great War* (London: Allen & Unwin, 1935); and Peter Chasseaud, *Artillery's Astrologers: A History of British Survey and Mapping on the Western Front, 1914-1918* (Lewes: Mapbooks, 1999).
[79] Predicted fire is "fire which is brought to bear when initial adjustment to the fall of shot is either impossible or undesirable for tactical reasons." Department of National Defence (DND), *B-GL-371-002/FP-001, Field Artillery, Volume 2, Duties of the Battery Commander and the Observer* (Ottawa: Commander Canadian Army, 1998), 233.
[80] Berton claims that McNaughton was "given caret blanche to focus his scientifically trained mind on the twin problems of pinpoint intelligence and pinpoint accuracy…. [He] would have to develop the techniques of counter-battery work from scratch." Berton, *Vimy*, 109.
[81] General Staff, General Headquarters, *SS193/3 Artillery Notes No. 3 – Counter-Battery Work* (February 1917).
[82] Ibid, 3.
[83] Fox, *Learning to Fight*, 81.
[84] Marble, *British Artillery on the Western Front in the First World War*, 152.

clarified the direction from GHQ.[85] Still, the system was mostly untried, and McNaughton and his operational research team needed to conduct further experimentation before the CBO was ready to support the operations of the Canadian Corps.

McNaughton went to visit the French Army in Verdun in January 1917 to learn about the latest innovations in counter-battery work. He has left conflicting evidence about his impressions of their methods. In a 1917 letter, McNaughton wrote, "I enjoyed my visit to the French Army very much indeed, and it has been very profitable."[86] However, in a 1963 interview, he stated that the French artillery in Verdun did not impress him. He found their methods and organization chaotic and inefficient.[87] He later claimed to have learned more about what not to do than what to do because the French "were a damned sloppy outfit as far as their artillery is concerned."[88] Curiously, both Brooke and Arthur Currie, who also visited the Verdun sector that winter, found the French innovations quite valuable. Brooke noted:

> We were taken to Army H.Q., Corps H.Q., Divisional and Brigade H.Q., and explained in detail all the plans for the attacks which had proved so successful. We were taken over the ground and under experts explained all the dispositions and the results of the attacks.… The whole trip was intensely interesting.[89]

Currie wrote in his report that the primary aim of the artillery before an attack must be neutralizing the enemy's guns.[90] Still, McNaughton did note that "[t]he advisability of leaving the destruction of Batteries to the last moment was impressed on us. The French consider that a Battery knocked out several days before the battle will have come to life again on the day of battle."[91] This lesson highlighted the importance of accurate and timely intelligence. In McNaughton's fire plans, he frequently re-engaged batteries that had been neutralized or destroyed to ensure suppression when the infantry began their attacks.[92]

McNaughton found the visit to British V Corps much more profitable. Brigadier-General Percy Radcliffe, the Canadian Corps brigadier-general general staff, suggested that McNaughton visit the British corps headquarters since it had established a reputation for counter-battery efficiency. At V Corps, McNaughton met Lieutenant-Colonel A.G. Haig, the CBSO, who has been described by one historian as "the father of the counter-battery staff."[93] Haig had been a professional artillery officer in the Royal

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[85] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 7 File 7, First Army Headquarters, No.1101, "Status and Duties of the Counter-Battery Lieutenant-Colonel in a Corps," 7 February 1917.
[86] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 4, C.B. 15/65, Letter from Lieutenant A.G.L. McNaughton to Lieutenant-Colonel Pievet, 5 June 1917.
[87] LAC, MG30-E100, General Sir Arthur William Currie Fonds (Currie Papers), Vol. 35, File 160, Memoranda and Reports, January – June 1917, Lieutenant-Colonel A.G.L. McNaughton, "Some Artillery Impressions Gained during a Visit to the Verdun Battlefields, 5-8 January 1917," 2, 11 January 1917.
[88] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 3, 7-8, 17 January 1963.
[89] LHCMA, Alanbrooke Papers, 5/2/13, "Notes on My Life," 58, January – February 1917.
[90] LAC, MG30-E100, Currie Papers, Vol. 35, File 160, Memoranda and Reports, January – June 1917, Major-General Arthur Currie, "Notes on French Attacks, North-East of Verdun in October and December 1916," 23 January 1917.
[91] LAC, MG30-E100, Currie Papers, Vol. 35, File 160, Memoranda and Reports, January – June 1917, Lieutenant-Colonel A.G.L. McNaughton, "Some Artillery Impressions Gained during a Visit to the Verdun Battlefields, 5-8 January 1917," 2, 11 January 1917.
[92] For instance, during the Battle of Passchendaele (31 July – 10 November 1917), German battery positions frequently needed to be reengaged after being subjected to 600 minutes of neutralizing fires to achieve the desired effect. LAC, RG9-III-D-3, Vol. 4957, File 504, War Diary (WD) – GOC RA, Canadian Corps, December 1917, Appendix C, "Canadian Corps Artillery Report on Passchendaele Operations, 17 October – 18 November 1917," 17, 21 December 1917.
[93] Dickson, "Leadership and Innovation," 151; and WO 372/8/194084, Medal Card of Alan Gordon Haig.

Garrison Artillery with experience in South Africa and the Northwest Frontier. In May 1916, Major-General C.E.D. Budworth, the chief gunner in Fourth Army, ordered Haig to form "a special counter battery organization…. The duties were to be the collection and collation of all information about the enemy artillery, and the schemes and orders for their destruction and neutralization."[94] Haig and his staff established many of the procedures necessary for counter-battery work: cooperation with the RFC, meticulous record-keeping, imagery analysis, use of novel detection techniques, and conduct of daily counter-battery shoots. These innovative procedures shaped those that McNaughton implemented for the Canadian Corps.[95] Lieutenant-Colonel Haig also impressed on McNaughton the importance of maintaining an accurate map to track German batteries. McNaughton adopted a similar product for the Canadian Corps CBO.[96] Ironically, Haig used a captured German map from the Somme that tracked the location and type of British guns, including the guns of the 11th (Howitzer) Brigade that McNaughton had commanded during that offensive. Learning best practices from the French and British armies helped McNaughton develop the counter-battery procedures for the Canadian Corps. However, he still needed to incorporate innovative technologies into the counter-battery system to locate and promptly engage German guns.

This study does not require a detailed examination of how sound-ranging and flash-spotting worked, but a brief explanation is warranted. Described by one historian as "the 'Manhattan Project' of the 1914-1918 war," sound-ranging was the more complex of the two technologies.[97] When a German gun fired, an officer activated the switch that turned on a series of microphones arrayed behind the frontline. These microphones detected the sound waves of the round travelling through the air and impacting. Based on the time intervals between the various microphones detecting the sound, the operator could pinpoint the location of the hostile piece. Flash-spotting required a series of observation posts established along the front equipped with telephones and survey instruments. When a gun fired, the observer would report his bearing to the flash. An officer in the headquarters used the "Flash and Buzzer Board" to ensure that the observers were reporting the same flash. Then he used their bearings to triangulate the position of the gun.

The BEF had used sound-ranging and flash-spotting for some time, and much experimentation had been carried out by 1917. The army fielded the first sound-ranging section in October 1915, commanded by Lieutenant Lawrence Bragg, a Territorial Force Royal Horse Artillery officer and winner of the 1915 Nobel Prize for physics.[98] Further experimentation throughout 1916 resulted in the introduction of the Tucker microphone (developed by Bragg and Lieutenant William Tucker, a physics lecturer at Imperial College London) and the formation of a Field Survey Company (FSC), Royal Engineers in each army.[99] The staff at GHQ collated the results of these trials and experiments and

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[94] Papers of Lieutenant-Colonel Alan Gordon Haig, "Haig's Recollections," n.d., courtesy of the late Major Dick Haig and family. I am grateful to Alan Jones for providing me with extracts from Haig's memoir. Curiously, neither Farndale, Marble, nor Strong make any mention of Haig's contribution to the development of the BEF's counter-battery capability.

[95] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 7, File 7, Lieutenant-Colonel A.G.L. McNaughton, C.B. 2/1, "Report to GOC RA Canadian Corps," 8 February 1917; and LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 3, 8-9, 17 January 1963.

[96] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 8, 1-2, 17 January 1963.

[97] Peter Chasseaud, "Field Survey in the Salient: Cartography and Artillery Survey in the Flanders Operations in 1917," in *Passchendaele in Perspective: The Third Battle of Ypres*, ed., Peter Liddle (London: Leo Cooper, 1997), 120.

[98] War Office, *Report on Survey on the Western Front*, 106-107. On the work done by Sir William Lawrence Bragg to develop sound-ranging, see William Van der Kloot, *Great Scientists Wage the Great War: The First War of Science, 1914-1918* (Stroud: Fonthill, 2014), 129-161.

[99] War Office, *Report on Survey on the Western Front*, 107. In 1918, the Canadian Corps formed its own Survey Section. LAC, RG9-III-D-3, Vol. 5006, File 697, WD – Canadian Corps Survey Section, 1-14 May 1918.

published *SS552 Sound Ranging* in March 1917.[100] Further experimentation, including testing done by the Canadian Corps, confirmed that the sound-rangers could conduct calibration and registration with the guns. The latter achieved a mean accuracy of 25 yards for range and 10 yards for line.[101] Sound-rangers could conduct this procedure when the weather made registration by a FOO or an air observer impossible. The BEF continued to refine this technique throughout the war.[102] Indeed, the present-day artillery still conducts this procedure.[103] Flash-spotting evolved along similar lines. Prewar doctrine mentioned flash-spotting, and much innovation had occurred in the intervening years. Lieutenant H.H. Hemming, a graduate of McGill University serving with the British Army, designed the "Flash and Buzzer Board" in May 1916, which the BEF widely distributed that November.[104]

Contrary to the Finan-Hurley argument, McNaughton had minimal involvement with the development and implementation of both sound-ranging and flash-spotting. The British Army had developed these systems by the time the Canadian Corps formed its CBO. McNaughton gets much of the credit for the development of these techniques since the CBO underwent its first experiment during the Battle of Arras (9 April – 16 May 1917), of which Vimy was the opening act. Arras was the first significant action for the BEF in 1917, and the first since corps had formed their CBOs and fully integrated sound-ranging and flash-spotting into their counter-battery system.[105] In postwar interviews, McNaughton exaggerated his role in the development of these techniques, and historians have propagated his claims since.[106]

Nor did McNaughton recruit three "civilian" scientists – Lawrence Bragg, Charles Darwin, and Lucien Bull – into his "research team" at Vimy.[107] Bragg and Darwin both served in the British Army, the former as an instructor at Depot FSC at GHQ and the latter as commander of U Section, 1 FSC, respectively.[108] During the Vimy operation, L and V Sections, not the section commanded by Darwin, supported the Canadian Corps.[109] Bull, the only civilian of the three, headed the Marey Institute in Paris and supported the British and French war efforts with scientific research.[110] Darwin and Bull served in the army for the remainder of the war. Bull continued his work at the institute. McNaughton may have met these men and encouraged the Canadian Corps to use their innovations, but they never served in the CEF. None felt so slighted working for "hidebound senior officers of the British Army" that they needed to quit their post and join the more "gregarious and open" Canadian Corps.[111] Bragg did later state that "an almost impassable barrier had been encountered between the military and scientific minds. The military

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[100] General Staff, General Headquarters, *SS552 Sound Ranging* (March 1917).
[101] Ibid, 6-9.
[102] General Staff, General Headquarters, "Notes on Sound Ranging: No. 38 – Notes on Ranging our Own Guns," (Printing Company, R.E. General Headquarters, 24 July 1918).
[103] DND, *Duties of the Battery Commander and the Observer*, 102-103.
[104] TNA, WO 339/78438, Harold Hemming Personnel File; and War Office, *Report on Survey on the Western Front*, 106-107.
[105] LAC, RG9-III-C-1, Vol. 3922, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, Lieutenant-Colonel A.G.L. McNaughton, "Notes on Counter-Battery Work in Connection with the Capture of Vimy Ridge by Canadian Corps, 9 April 1917," 7, Appendix 6, "Comparison of Calibres of Hostile Batteries, 29 April 1917," n.d.
[106] Nicholson, *The Gunners of Canada*, 315n1; Swettenham, *McNaughton*, 78-83; Williams, *Byng of Vimy*, 144-146; Berton, *Vimy*, 164-166; Finan and Hurley, "McNaughton and Canadian Operational Research at Vimy," 10; and Cook, *Shock Troops*, 34-37.
[107] Finan and Hurley, "McNaughton and Canadian Operational Research at Vimy," 10; and Berton, *Vimy*, 164.
[108] Chasseaud, *Artillery's Astrologers*, 98, 167-168.
[109] LAC, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery, Vol. 3916, Folder 54, File 6, CBO, "Artillery Order No. 18," 2, 7 April 1917.
[110] Chasseaud, *Artillery's Astrologers*, 97-98.
[111] Berton, *Vimy*, 164.

thought us scientists far too visionary and gadgetry to be of any help in the field."[112] Bragg's remarks though hardly square with McNaughton's recollections with the innovation that occurred in the BEF.

> [T]here were constant conferences on the levels of all formations from armies down and, if any corps had developed a new way of doing a particular kind of operation … they probably hardly hadn't got their boots off until they were being asked to come back and explain the reason for their success or failure to look at it and see what had gone wrong.[113]

Perhaps Bragg felt slighted. The military could not afford to waste precious resources on a project that did not seem to satisfy an operational need. Operational research involved innovation, but it also entailed discarding projects that did not deliver results.

The Canadian Corps CBO also made extensive use of air observation to take photographs of hostile batteries and to adjust artillery fire. *SS193/3* emphasized the capabilities of aircraft for counter-battery work, and by 1918, each corps had an attached RFC squadron.[114] At Vimy, air observers adjusted the fire for seventy-five percent of all counter-battery shoots.[115] And that percentage only increased at the tempo of operations picked up during the Hundred Days campaign (8 August – 11 November 1918). Aerial photographs provided more intelligence than flash-spotting or sound-ranging – calibre, disposition, degree of protection, and battle damage assessment. The image, however, had to be carefully analyzed. Without this detailed study, "You could look at [the photograph] till the cows come home. You got to put a fellow on who knows how to interpret it, knows what he sees, be able to identify what he sees and to mark it and put the marks on a map."[116] The courses in imagery analysis that intelligence officers like Davidson completed helped them to glean useful information from these photographs. Air observers could locate defiladed German gun positions, which could not always be located by FOOs or flash-spotters. Aircraft also did not have the lengthy setup time of the sound-ranging microphones, although weather, anti-aircraft fire, and enemy planes all could hinder aerial observation. McNaughton and his staff could not do anything about the weather or enemy aircraft, but they did figure out ways to suppress the enemy's air defences while RFC flyers observed and made corrections for counter-battery shoots.[117] This full integration of assets required a robust and innovative staff like the CBO to manage.

Counter-battery shoots observed and adjusted by the RFC provided the CBO with prompt intelligence and a reasonably accurate determination of battle damage assessment. In his memoir, Canadian ace Major William A. Bishop described the process of a counter-battery shoot observed from the air.

> [Y]ou fly on until you pick up the four mounds that indicate the German battery position. You fly rather low to get a good look at it. The Huns generally know what your coming means and they prepare to take cover. You return a little way toward your own lines and signal to your battery to fire. In a moment you see the flash of a big gun. Then nothing seems to happen for an eternity. As a matter of fact twenty to thirty seconds elapse and

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[112] Swettenham, *McNaughton*, 77.
[113] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 2, 8, 17 January 1963.
[114] General Headquarters, *SS193/3 Artillery Notes No. 3 – Counter-Battery Work*, 5; and LHCMA, Alanbrooke Papers, 3/10, "Evolution of Artillery in the Great War 1914-1918," 47.
[115] LAC, MG30-E100, Currie Papers, Vol. 35, File 160, Memoranda and Reports, January – June 1917, Lieutenant-Colonel A.G.L. McNaughton, C.B. 20/8, "Counter-Battery Office Report," 2, 25 June 1917.
[116] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 2, 10, 17 January 1963.
[117] LAC, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery Vol. 3915, Folder 51, File 1, Counter-Battery Office, C.B. 3/5, "Memorandum on Co-operation with the RFC," 18 February 1917.

> then fifty yards beyond the German battery you see a spurt of grey-black earth spring from the ground. You signal a correction of the range. The next shot goes fifty yards short. In artillery language you have "bracketed" your target. You again signal a correction, giving a range just in between the first two shots. The next shell that goes over explodes in a gunpit. "Good shooting," you signal to the battery, "carry on." This particular battery is silenced for good and all.[118]

Air observers executed the complete targeting cycle by detecting German batteries, adjusting the counter-battery fire, and reporting the battle damage assessment to the CBO. Improvements to the communications equipment during the war significantly improved the efficiency and utility of air observers, and they remain in use in the present day.

The senior commanders and staff of the Canadian Corps supported the work done by McNaughton and his staff. More than any invention or new staff procedure, McNaughton identified the support of these officers as the reason for the success of the CBO.[119] Perhaps the patronage of successful, competent officers like Radcliffe, Julian Byng, and Currie, explains why the Canadian Corps is well known for its counter-battery work, almost to the complete exclusion of other British corps. Lieutenant-Colonels John Dill and Edmund Ironside, British staff officers serving with the Canadian Corps, frequently visited the CBO.[120] Both went on to serve as Chiefs of the Imperial General Staff during the Second World War. Radcliffe first set McNaughton up for success by introducing him to counter-battery pioneers in V Corps and ensuring that the CBSO did not get encumbered with routine administration.[121] Byng and Currie also helped by getting McNaughton and his staff the resources that they needed. McNaughton wrote:

> The credit for this is largely due to our Corps Commander [Currie], who in developing his policy of giving his infantry the maximum of support, was invariably sympathetic in his attitude towards the Canadian gunners and gave the necessary means and encouragement to surmount the difficulties which from time to time faced us.[122]

McNaughton also got on with the two head gunners in the Canadian Corps headquarters. Morrison supported the operational research done by the CBO and got McNaughton the guns and ammunition that he needed.[123] He was not a brilliant or scientific gunner, but he did leverage his more talented subordinates, like McNaughton and Brooke – the two officers who were the real brains of the Canadian artillery in the First World War.[124] Another officer noted, "The development – to the highest degree – of Counter-Battery work was entirely due to McNaughton. 'Dinky' Morrison, though admirable in other respects, was 'Boer War' in matters of gunnery techniques."[125] The relationship was not quite as harmonious with the commander of the Canadian Corps Heavy Artillery (CCHA), Brigadier-General R.H. Massie.[126] McNaughton claimed that this professional British garrison artilleryman resented the control that the "amateur" had over his guns for counter-battery fire.[127] That may well have been the case,

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[118] William A. Bishop, *Winged Warfare* (New York: George H. Doran Company, 1918), 27-28
[119] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 2, 14, 17 January 1963.
[120] Swettenham, *McNaughton*, 75.
[121] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 3, 3-5, 17 January 1963.
[122] A.G.L. McNaughton, "The Development of Artillery in the Great War," *Canadian Defence Quarterly* Vol. XI, no. 2 (January 1929): 163.
[123] Cook, "The Gunners at Vimy," 111.
[124] LHCMA, Alanbrooke Papers, 5/2/13, "Notes on My Life," 59, February – April 1917.
[125] General H.D.G. Crerar Letter to Colonel G.W.L. Nicholson, 10 March 1965, quoted in Swettenham, *McNaughton*, 97.
[126] WO 372/24/42474, Medal Card of R.H. Massey.
[127] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 8, 4, 17 January 1963.

but the tension between the two officers does not seem to have ever affected the efficiency of the counter-battery work of the Canadian Corps.

Support for the counter-battery work of the Canadian Corps extended up to Field Marshal Haig. Despite the supposed concerns that the Canadians expended prodigious quantities of artillery ammunition, GHQ almost always gave the Canadian Corps the resources that it wanted.[128] Morrison recalled that when Haig would visit the Canadian Corps, he would ask, "Have they given you all the ammunition that you want?"[129] McNaughton recalled that when he wanted to do experimentation with sound-ranging sections, he would request a section from GHQ, and the staff always actioned the request immediately. He noted, "We never lacked for these facilities right up to the limit of what we could employ, you see, because they all wanted to come to us and the GHQ people knew we'd make good use of them."[130] Patronage went a long way in ensuring that McNaughton was able to disseminate his lessons learned to other corps and learn from others.

The first significant experiment for the Canadian Corps CBO came at Vimy Ridge in the spring of 1917. The operational research that improved detection techniques and shaped the targeting process controlled by the CBSO, and encapsulated in *SS193/3*, paid off. The Canadian Corps had occupied the front at Vimy since November 1916, so air observers, sound-rangers, flash-spotters, and FOOs had been collecting artillery intelligence and submitting this information to the CBO for four months before the operation.[131] The British had reinforced the heavy artillery of the Canadian Corps for the attack, so McNaughton wielded 245 heavy guns to prosecute hostile batteries.[132] Aircraft and FOOs provided battle damage assessments from these engagements, and the hostile battery was either removed from the target list or reengaged.[133] Morrison exaggerated when he claimed that all of the German artillery had "been discovered and successfully dealt with."[134] Nevertheless, the counter-battery programme, developed by McNaughton, was effective. Before zero hour, at 0530hrs on 9 April, all but three German battery positions at Vimy Ridge had been identified, and Davidson inferred that these guns remained silent during the battle.[135] The confined terrain of the battlefield forced the Germans to group their batteries tightly together, which made finding them more manageable.[136]

Experimentation did not answer all questions and some fine-tuning was required based on what happened at Vimy. At zero hour, when the rolling barrage began, the guns tasked with counter-battery fire laid neutralizing fires on forty-seven German batteries.[137] In his intelligence reports, Davidson listed these batteries as active or possibly active. The Canadian Corps sustained 10,602 casualties, including 3,598

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[128] Swettenham, *McNaughton*, 161-162; and LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 12, 7, 15 February 1963.
[129] LAC, MG30-E81, Morrison Papers, Vol. 2, Artillery Corps Notes and Pamphlets, "The Canadian Artillery in the Great War," 8, n.d.
[130] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 3, 11, 17 January 1963.
[131] Chasseaud, *Artillery's Astrologers*, 270.
[132] LAC, RG9-III-D-3, Vol. 4957, File 503, WD – GOC RA, Canadian Corps, April 1917, Appendix I, G.3. S.156/31/2., "Canadian Corps Artillery Instructions for the Capture of Vimy Ridge, Appendix B, Distribution of Heavy Artillery," 28 March 1917.
[133] LAC, RG9-III-D-3, Vol. 4973, File 561, WD – Canadian Corps Heavy Artillery, 1 March – 8 April 1917.
[134] Morrison, *Morrison*, 124.
[135] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, "Notes on Counter-Battery Work in Connection with the Capture of Vimy Ridge by Canadian Corps, 9 April 1917," 18.
[136] Farndale, *History of the Royal Regiment of Artillery*, 165.
[137] Cyril Falls, *History of the Great War: Military Operations, France and Belgium, 1917, Volume I, The German Retreat to the Hindenburg Line and the Battle of Arras* (London: His Majesty's Stationery Office, 1940), 315; and LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3," Notes on Counter-Battery Work in Connection with the Capture of Vimy Ridge by Canadian Corps, 9 April 1917," 17, 19.

fatalities.[138] Machine-gun and rifle fire alone could not have caused all those casualties. Shellfire accounted for the highest percentage of severe wounds – approximately seventy-two percent.[139] Even so, Vimy confirmed that the *SS193/3* worked, although some minor adjustments could stand to be made. After the battle, McNaughton and the staff studied the organization and procedures of the CBO. They used records of calls for fire, reconnaissance of captured gun positions, enemy maps, and the reports of FOOs for evidence. The staff captured their findings in a thorough report that made several recommendations to improve the system created by *SS193/3*. In the report, the CBSO wrote that he did not have enough officers and clerks to manage the analysis of intelligence and production of fire orders. McNaughton recommended that the corps permanently assign an intelligence officer, operations officer, three orderly officers, and five clerks to the CBO.[140] The report scrutinized the effectiveness of the counter-battery fires and made recommendations for the employment of each weapon system based on the target. For instance, the report advised against using 60-pounder guns for destructive shoots since "shells were not sufficiently powerful against the very strong German gun emplacements."[141] A separate report prepared by Captain W. Eric Harris, the Canadian Corps chemical advisor, noted the usefulness of gas for counter-battery work against gun positions that had already been targeted but remained in action.[142] The corps artillery could quickly implement these recommendations. Addressing the shortcomings in the intelligence-gathering and analysis required more thought.

The intelligence collected and analyzed before Vimy was mostly accurate. Of the forty-seven German batteries engaged at zero hour, McNaughton determined that eighty-three percent were active.[143] Intelligence is never perfect, though. The report also noted that eighteen percent of the thirty-four hostile battery positions that Davidson had assessed as "not active" fired on the Canadian Corps during the battle.[144] With better intelligence, McNaughton might have employed the ammunition and guns wasted on non-active batteries and used them against active batteries or even assigned them for on-call tasks against batteries that suddenly come back to life. Thus, a report on the counter-battery battle at Vimy noted that, in sectors where the Canadian Corps had limited time to collect intelligence, guns needed to be more responsive to calls for fire from air observers. The report also verified that the information collected by the sensors corresponded to the location, disposition, and calibre of the German guns. The sound-rangers, for instance, correctly established the calibre and arcs of fire of sixty-five percent of the hostile pieces positioned on the ridge.[145] To confirm hostile batteries, McNaughton noted, "in no case should a [hostile battery] be confirmed on less than two reports from entirely different sources."[146] Not all experimentation resulted in technical changes, and the staff intended to address the intelligence shortcomings at Vimy in the counter-battery programmes of future battles.

The Canadian Corps CBO disseminated its report on counter-battery work to other formations so their staff could study it. Historian Sanders Marble writes that the corps did not widely distribute the

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[138] Nicholson, *Official History of the Canadian Army in the First World War*, 265.
[139] Mitchell, *Medical History of the War*, 41.
[140] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, "Notes on Counter-Battery Work in Connection with the Capture of Vimy Ridge by Canadian Corps, 9 April 1917," 2.
[141] Ibid, 12.
[142] LAC, RG9-III-C-1, Vol. 3922, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, "Notes on Artillery preparation and Support of the Attack on Vimy Ridge. April 9th.1917," Captain W.E. Harris, No. 11/58, "Report on the Preparation of Gas Shell Bombardments. Canadian Corps – Attack on Vimy Ridge, 9 April 1917," 2, n.d.
[143] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, "Notes on Counter-Battery Work in Connection with the Capture of Vimy Ridge by Canadian Corps, 9 April 1917," 18-19.
[144] Ibid, 10.
[145] Ibid, 7.
[146] Ibid, 10.

report, at least not officially.[147] This conclusion, however, is incorrect. McNaughton sent a full copy of the report with appendices to Lieutenant-Colonel Pievet, a French artillery officer in the French XI Corps.[148] McNaughton did not only send this report to Pievet to share the findings of the report. He wanted the French artillery officer to provide criticisms based on his own extensive experience with counter-battery. McNaughton had learned much from Pievet's demonstration of massed, destructive shoots on enemy guns controlled from an aeroplane. This exchange is but one example of what Aimée Fox describes as "an effective Anglo-French lessons learned partnership."[149] More informally, Brooke shared his notes of the operation with a colleague at X Corps, who incorporated some of the lessons learned at Vimy during the Battle of Messines (7-14 June 1917).[150] The staff did not always need to disseminate learning through formal channels.

Further experimentation at the Battle of Hill 70 (15-25 August 1917) confirmed what worked and exposed some limitations that ought to be considered in counter-battery planning. The counter-battery programme that McNaughton designed for Hill 70 had many similarities to the programme for Vimy. In the weeks before the offensive, the artillery conducted destructive shoots, although frequent periods of inclement weather limited aerial observation. The entry in the Canadian Corps Heavy Artillery war diary for 4 August is typical. "Aeroplane observation again impossible owing to bad visibility, but Counter Batteries carried out neutralization and one destruction shoot was carried out with ground observation."[151] Tested at Vimy, the system of systems all linked into the CBO ensured that some counter-battery work could continue even in adverse weather conditions. At 0425hrs 15 August, zero hour, the 111 heavy guns allocated to McNaughton engaged German batteries with "an intense neutralizing fire."[152] To further suppress German batteries, the fire plan stated, "a free use will be made of 4.5" and 60-pdr. gas shell[s]."[153] Vimy had also proved the usefulness of gas. Enemy gunners could not calculate firing data, issue orders, or check sights easily while wearing a respirator, so gas was fully integrated into the counter-battery plans at Hill 70, where the counter-battery programme had neutralized between forty and sixty-three hostile batteries of an estimated 102 battery positions.[154] Although less effective percentage-wise than Vimy, the counter-battery programme at Hill 70 had fewer guns and aircraft due to the broader offensive in Flanders and much of the fire was predicted, which of course was less accurate than observed fire.[155] Guns did not fire on batteries suspected to be inactive – another lesson from Vimy – and they responded to calls for fire from air observers once the Germans "unmasked" their hidden guns to shoot their defensive fire plan.[156] At Hill 70, McNaughton and the CBO incorporated the lessons from Vimy

[147] Marble, *British Artillery on the Western Front in the First World War*, 183.
[148] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 4, C.B. 15/65, Letter from Lieutenant-Colonel A.G.L. McNaughton to Lieutenant-Colonel Pievet, 5 June 1917.
[149] Fox, *Learning to Fight*, 142.
[150] Marble, *British Artillery on the Western Front in the First World War*, 183.
[151] LAC, RG9-III-D-3, Vol. 4973, File 561, WD – Canadian Corps Heavy Artillery, 4 August 1917.
[152] LAC, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery, Vol. 3916, Folder 54, File 9, Counter-Battery Office, "Canadian Corps Artillery Order No. 39," 1, 1 August 1917.
[153] LAC, RG9-III-D-3, Vol. 4957, File 504, WD – GOC RA Canadian Corps, July 1917, Appendix A, Major A.F. Brooke, "Artillery Order No. 52, Artillery Plan for the Capture of Hill 70," 3-4, 20 July 1917.
[154] LAC, RG9-III-D-3, Canadian Corps Headquarters Royal Artillery, Vol. 3899, Folder 12, File 1, CBO, C.B. 7/27, "Weekly Intelligence Summary of 16-22 August 1917," 2, 23 August 1917; Nicholson, *Official History of the Canadian Army in the First World War*, 286; and Farndale, *History of the Royal Regiment of Artillery*, 205. Farndale provides the more generous assessment. Tim Cook provides a useful assessment on the use of gas during the Battle of Hill 70. Tim Cook, "The Fire Plan: Gas, Guns, Machine Guns, and Mortars," in *Capturing Hill 70: Canada's Forgotten Battle of the First World War*, Douglas E. Delaney and Serge Marc Durflinger, eds., (Vancouver and Toronto: UBC Press, 2016), 102-136.
[155] Nicholson, *The Gunners of Canada*, 297.
[156] LAC, RG9-III-D-3, Canadian Corps Headquarters Royal Artillery, Vol. 3899, Folder 12, File 1, CBO, C.B. 7/27, "Weekly Intelligence Summary of 16-22 August 1917," 1, 23 August 1917.

and applied newer methods like gas for neutralization and predicted fire. These methods worked, and the CBO incorporated them into future counter-battery programmes.

Passchendaele (26 October – 10 November 1917) may have marked the nadir of the effectiveness of the Canadian Corps CBO, but operational research continued. Terrain, short planning cycles, poor intelligence, and worn-out guns all hindered counter-battery work.[157] The morale of the gunners suffered as well. McNaughton recalled, "Orders were being given to fire ammunition that was never, in fact, being fired."[158] The report prepared by the staff after the battle attributed the success of the operations not to counter-battery work but "to the ability of the Infantry to choose forming-up positions, just clear of the localities habitually shelled."[159] Unlike earlier operations, the report mostly relied on anecdotal evidence.

> [T]he effects of our Counter Battery work are hard to estimate, as it is almost impossible to determine whether the enemy stops shelling because he is silenced, or owing to his programme being finished. It is however reported that the response of the counter Batteries was always prompt when neutralizing fire was called for, and that in many cases hostile shelling ceased soon after our batteries had opened.[160]

Still, the staff took stock of the situation and identified several shortcomings that persisted with the counter-battery system.

The CBO found communications and the intelligence-gathering system deficient at Passchendaele. McNaughton set up an experiment to test communications within the counter-battery system. From an observation post, he sent a message to the CBO by carrier pigeon and by wireless radio.[161] The pigeon arrived at the CBO in half an hour while the radio message did not get through until the next day. Technology had its limits, and the CBO found that primitive communications undermined its flexibility. The artillery was unable to fully benefit from the capabilities of the radio for command and control of guns until the Second World War. Poor intelligence had hindered the effectiveness of counter-battery work from the moment the Canadian Corps arrived in Flanders. When the Canadian Corps relieved II ANZAC Corps on 18 October 1917, McNaughton complained to Morrison about the slackness of their counter-battery methods. "It is almost impossible, from the Records left by the Corps which the Canadian Corps relieved, to establish any comparison between the results of Counter Battery Intelligence obtained this week with those obtained last week."[162] Sound-ranging and flash-spotting sections had difficulty keeping up with the infantry, so intelligence collection almost depended entirely upon aerial observation. During the attack launched on 30 October, for instance, the counter-battery groups responded to more than seventy calls for fire from the RFC.[163] The staff recommended that the artillery, not the intelligence branch, should control the ground sensors. Ultimately, though, the intelligence branch retained command over the flash-spotters and sound-rangers. Not every finding and recommendation to

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[157] LAC, RG9-III-D-3, Vol. 4957, File, 504, WD – GOC RA Canadian Corps, December 1917, Major A.F. Brooke, Appendix C, "Canadian Corps Artillery Report on Passchendaele Operations Oct. 17th to Nov. 18th, 1917," 12-18, 21 December 1917.
[158] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 6, 15-16, 17 January 1963.
[159] LAC, RG9-III-D-3, Vol. 4957, File, 504, WD – GOC RA Canadian Corps, December 1917, Major A.F. Brooke, Appendix C, "Canadian Corps Artillery Report on Passchendaele Operations Oct. 17th to Nov. 18th, 1917," 14, 21 December 1917.
[160] Ibid, 30.
[161] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 7, 5, 17 January 1963.
[162] LAC, MG30-E81, Morrison Papers, Vol. 4, Materiel, Hostile Batteries, Lieutenant-Colonel L.P. Napier, C.B.7/36/1, "Memorandum from CBSO Canadian Corps to GOC RA Canadian Corps," 25 October 1917.
[163] LAC, MG30-E81, Morrison Papers, Vol. 2, Artillery Corps Operations, Major-General E.W.B. Morrison, "Operations of the Canadian Corps during October 1917," 8, n.d.

come from experimentation found its way into practice. During the Hundred Days, these systems proved impractical due to their lengthy set-up time and advances that outstripped their detection range. Nothing diminished the importance of air observation during the war, however. In fact, it became even more important in the open warfare of the Hundred Days.

Throughout the winter of 1917-1918, as they had done the previous year, staff officers continued to disseminate the results of their operational research and tweak the counter-battery system. During this period, the Canadian Corps artillery had the opportunity to carry out training and "experimental work."[164] And they were not alone. Sound-ranging sections held regular conferences with the other sections to disseminate new ideas and share best practices.[165] Not only did the corps submit the results of these experiments to army headquarters, but they also submitted them to GHQ as well, at the request of GHQ. Only ten days after the Battle of Passchendaele ended, Second Army requested information "With the object of gathering all available information from experience gained during the recent operations."[166] Second Army listed eighteen points to be addressed. Questions that asked for an "appreciation," "estimated effect," and "available figures" all required operational research to be adequately answered. The responses to questionnaires like this could be studied by the army artillery staff and shared across the BEF. Formations learned from each other so that they did not need to relearn the same lessons.[167] It also helped interoperability. British guns frequently supported the Canadian Corps, but standardized methods meant that it did not pose any significant challenges. During the Hundred Days campaign, more than twenty-five percent of the British heavy guns served with the Canadian Corps. McNaughton recalled, "We had no trouble with coordination, we had what we wanted, what was essential was reduced to a drill."[168]

Learning continued between the BEF and French Army as well. A lecture delivered by General Barbier, the senior gunner in French XXI Corps, on the attack at Malmaison (23-27 October 1917) yielded some crucial lessons for counter-battery work.[169] GHQ sent an officer to attend this lecture and distributed his notes across the BEF. In particular, the Canadian Corps replicated one lesson contained in this report during the Hundred Days. "The Germans had a considerable strength in artillery … which they were unable to use owing to the rapidity and depth of the attack, which necessitated the immediate displacement of a great number of their batteries."[170] Forcing guns to move was just as effective as neutralizing them with gas or high explosive, and many of the objectives for the infantry during the Hundred Days campaign were of sufficient depth to force the Germans to withdraw or abandon their field guns.

Despite the lessons learned from other CBOs, assistance from the scientific community, and support of the chain of command, McNaughton and his staff contended with challenges that complicated

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[164] MG30-E81, Morrison Papers, Vol. 2, Artillery Corps Notes and Pamphlets, "The Canadian Artillery in the Great War," 8, n.d.
[165] Innes, *Flash Spotters and Sound Rangers*, 153.
[166] LAC, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery, Vol. 3915, Folder 50, File 3, R.A. Canadian Corps, 760/21-6, "Questionnaire on Experience Gained While on Second Army Front," 20 November 1917.
[167] Lessons learned from breakdowns in communications within other British corps during the Spring Offensive (21 March – 18 July 1918) led McNaughton to develop a new procedure to communicate with aircraft from the guns. LAC, MG30-E81, Morrison Papers, Vol. 4, Materiel, Artillery Contact Aeroplanes, Lieutenant-Colonel A.G.L. McNaughton, C.B. 497/3-3, "Artillery Contact Aeroplanes during Mobile Warfare," 29 April 1918.
[168] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 2, 13, 17 January 1963.
[169] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3921, Folder 5, File 1, Major R.W. Benson, C.B. 233/14-5, "La Malmaison Attack, Notes on Lecture by General Barbier, Commanding the Artillery of the 21st Corps," 21 February 1918.
[170] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3921, Folder 5, File 1, Headquarters *Groupe d'armées du Nord*, V.B. 17, "Artillery Notes on the Battle of La Malmaison Attack," 3, 6 November 1917.

their operational research. First, McNaughton and his team did not work in typical laboratory conditions. The German Army was a first-class enemy that sought to evolve its tactics and mitigate the effectiveness of British artillery and counter-battery fire.[171] In other words, the test subject fought back. At Hill 70, for instance, German gas bombardments of Canadian heavy guns during the night of 14-15 August 1917 "almost completely neutralized" the Canadian batteries.[172] Second, the CBO and the heavy guns that fired for it were almost always in "contact" with the enemy. The difficulty of moving heavy guns and the logistical apparatus that sustained them meant they generally stayed in the same place and engaged in long-range exchanges with enemy guns. So, while being static on a single front usually permitted the intelligence staff to develop a thorough appreciation of the enemy, it also meant that McNaughton and his staff could not fully dedicate themselves to operational research.

The primary aim of the CBO was to win the artillery firefight, and operational research was big part of helping to achieve that aim. Much of the analysis occurred during operational lulls or the after-action review process. Some testing did occur behind the lines, but the staff conducted much of it during operations. One trial that occurred in June 1918 sought to determine if an observer could fix the location of the gun firing airburst munitions by observing the burst.[173] The theory worked and proved useful when the observer could not see the point of impact due to dead ground or soft terrain. Another trial in July tested the effect of wearing box respirators and steel helmets while shooting a bearing with a prismatic compass.[174] The test found that the metal affected the accuracy of the compass by as much as ten degrees. The report recommended that, when using a compass, the respirator not be worn on the chest but kept down at the side. Like testing the efficacy of the wireless against the pigeon for communications at Passchendaele, these experiments yielded results that could be applied in future operations and shared with others to assist with their counter-battery work.

Operational research conducted by the Canadian Corps also casts doubt on claims about the accuracy of predicted fire in 1917 and 1918. One study published in June 1918 used all the pieces of ordnance in service with the Canadian Corps against three types of targets: a fifty-yard-by-ten-yard target parallel to the line of fire representing a battery in enfilade, a fifty-yard-by-ten-yard target perpendicular to the line of fire representing a battery under frontal fire, and a ten-by-ten-yard targets representing a dugout, trench junction, or cable centre (see appendix A, page 56).[175] The results proved disappointing. Out of every 100 predicted rounds fired at the target, only 0.2 to 1.5 rounds impacted within the fifty-yard-by-ten-yard target.[176] The report noted, "the Errors introduced in Map shooting are very large, and the expectation of hitting a Target is consequently reduced to a low figure."[177] Interestingly, the test also

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[171] Strong and Marble, *Artillery in the Great War*¸ 125-127, 153-154.
[172] LAC, RG9-III-D-3, Canadian Corps Headquarters Royal Artillery, Vol. 3899, Folder 12, File 1, CBO, C.B. 7/26, "Weekly Intelligence Summary of 9-15 August 1917," 1, 16 August 1917
[173] LAC, RG9-III-D-3, Vol. 5006, File 697, WD – Canadian Corps Survey Section, 8 June 1918.
[174] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 7, File 4, Canadian Corps General Staff, G.632/23-9, "Report on Variations in Prismatic Compass Bearings Caused by Respiratory and Helmet," 23 July 1918.
[175] LAC, MG30-E81, Morrison Papers, Vol. 4, Materiel, Artillery Contact Aeroplanes, CBO, C.B. 636/20, "Results of the Shoots by the Canadian Corps Artillery with Aeroplane Observation, 26 December 1917 – 4 May 1918," 17 June 1918.
[176] LAC, MG30-E81, Morrison Papers, Vol. 4, Materiel, Artillery Contact Aeroplanes, CBO, C.B. 636/20, Appendix D, "Accuracy of Fire Based on Appendix 'B' and Range Tables of the Various Calibres," 17 June 1918.
[177] LAC, MG30-E81, Morrison Papers, Vol. 4, Materiel, Artillery Contact Aeroplanes, CBO, C.B. 636/20, "Results of the Shoots by the Canadian Corps Artillery with Aeroplane Observation, 26 December 1917 – 4 May 1918," 3, 17 June 1918. These results are also comparable to the data collected by No. 2 ORS on the accuracy of predicted fire during Operation VERITABLE (8 February – 11 March 1945), which determined five percent of predicted rounds hit the 100 yards squared target. Copp, ed., "Report No. 31 The Accuracy of Predicted Fire: Operation VERITABLE," in *Montgomery's Scientists*, 295.

determined that firing artillery in enfilade, which was the preferred method, offered no discernible advantage for accuracy over engaging a target frontally.[178] Still, artillery is an area weapon, and not all rounds need to impact accurately on the target to achieve neutralization or suppression effects. As predicted fire became the norm in 1918, the artillery could not destroy German batteries like they had after lengthy registration shoots in 1917. Instead, counter-battery programmes emphasized neutralization.

Planning and preparations for the operation at Amiens (8-12 August 1918) took place in complete secrecy, and the Canadian Corps only arrived in sector the week before the attack.[179] These constraints severely limited the ability to collect artillery intelligence, register the guns, and conduct preparatory fires against hostile batteries. Aware that the trialling done in June had demonstrated the limitations of predicted fire, McNaughton prepared a counter-battery plan that massed the fires of at least two batteries per hostile battery at the start of the attack.[180] In his own words, he intended to "swamp" the German guns with neutralizing fire.[181] Statistically, some of these rounds had to strike the target, and a lot of close-enough rounds would have had some neutralizing effect. After the battle, an examination of the hostile battery positions by the staff found a large dispersion in the fall of shot, "but the MP.I's [mean point of impact] were on target."[182] Historian Shane Schreiber accurately summarized the results of the counter-battery fire. "[S]ilenced or preoccupied at the exact moment they were most needed, the German artillery batteries were to be … wiped from the face of battle for the initial assaults on 8 August."[183] Some German batteries did lay down defensive fires, but within two hours of the start of the attack, German indirect fire had all but ceased when the Canadian infantry seized many of the German gun positions.[184] Not only did this force the hostile batteries to ceasefire, it also rendered them more vulnerable to destruction in subsequent engagements since they would occupy less prepared positions.[185]

The after-action review from Amiens also portended many of the findings of operational research reports prepared after other battles during the Hundred Days campaign. These included: the importance of flexibility for guns to engage opportunity targets identified by the Royal Air Force (RAF), the limitations of surveyors during mobile warfare, the difficulty of bounding the heavy guns forward to keep in range, and the advantages of infantry breaking into the enemy's depth to dislocate guns.[186] By 1918, fires still supported the close battle but principally focused on the enemy's depth, particularly command and control nodes and artillery.[187] British and Canadian artillery fought the deep battle with heavy guns and

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[178] General Staff, General Headquarters, *SS139/4 Artillery Notes No. 4 – Artillery in Offensive Operations* (London: His Majesty's Stationery Office, February 1917), 26-28.
[179] LAC, RG9-III-D-3, Vol. 4957, File 504, WD GOC RA Canadian Corps, 31 July 1918. The Australian Corps did, however, give McNaughton all the intelligence that they had on the German gun positions in the Canadian Corps sector during the handover. Swettenham, *McNaughton*, 138.
[180] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3923, Folder 10, File 4, CBO, C.B. 872/4-2, "General Notes on Operations Commencing August 8th, 1918," 22 August 1918.
[181] LAC, MG30-E133, McNaughton Papers, Series I, Vol. 2, War Diaries – Miscellaneous, Letter from Lieutenant-Colonel A.G.L. McNaughton to his wife, 15, 7-8 August 1918.
[182] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3923, Folder 10, File 4, CBO, C.B. 872/4-2, "General Notes on Operations Commencing August 8th, 1918," 1, 22 August 1918.
[183] Schreiber, *Shock Army of the British Empire*¸ 44.
[184] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3923, Folder 10, File 4, CBO, C.B. 843/4-2, Memorandum on Employment of Artillery at Amiens, 19 August 1918
[185] Staffs noted this finding and dislocating indirect fire assets through manoeuvre remained a planning consideration through the Second World War. During the planning for Operation TOTALIZE (8-9 August 1944), Lieutenant-General Guy Simonds, commander of II Canadian Corps, considered the need to overrun German mortar positions before his infantry could consolidate. Douglas E. Delaney, *Corps Commanders: Five British and Canadian Generals at War, 1939-1945* (Vancouver and Toronto: UBC Press, 2011), 228-229.
[186] LAC, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery, Vol. 3923, Folder 11, File 8, CBO, "Notes on Counter-Battery Support and Capture of Mont Houy by the Canadian Corps, 1 November 1918," 3 February 1919.
[187] Bailey, "British Artillery in the Great War," 31.

the cooperation of the RAF, which conducted early forms of close air support and battlefield air interdiction.[188] Operational research helped the staff identify the "high-payoff targets" that could be attacked by fires and cause the most significant damage and disruption to the enemy. The BEF now had the intellectual capacity to conceive of an operation like the masterpiece 1991 Operation DESERT STORM. In contrast to earlier periods in the war, the operational art exceeded what technology could do.

After Amiens, the high operational tempo limited the ability of the staff to conduct after-battle reconnaissance and prepare analytical reports like they did in 1917. There just was not time. Between Amiens and the Armistice on 11 November 1918, the Canadian Corps only had four pauses of a week or more between major operations, the longest being twenty-four days, the shortest being nine days.[189] Still, no one knew that the war would end on 11 November, and the BEF continued to collect data, whatever data it could – mostly on artillery intelligence collection – for analysis to refine its methods for future engagements. McNaughton, promoted to brigadier-general and appointed CCHA after the Battle of Cambrai (8-10 October 1918), modified the command structure of the heavy artillery in the Canadian Corps.[190] Based on his assessment of mobile warfare and the necessity of better linkages between the CBO and the heavy guns, he retained responsibility for counter-battery fire and reduced the authority of Lieutenant-Colonel H.D.G. Crerar, his protégé and successor as CBSO, to that of any other artillery staff officer in the corps headquarters. This demotion severed the direct link of the CBSO to the corps commander and the GOC RA in the Canadian Corps at a time when the CBSOs in other British corps became "more of an all-round artillery commander."[191] Impressed by the performance of the Canadians at Valenciennes (1-2 November 1918), the War Office adopted the staff structure of the Canadian Corps artillery in 1919, and the Royal Artillery used it during the North African and Italian campaigns of the Second World War.[192] During mobile warfare period of 1918, artillery intelligence relied almost exclusively on information from air observers, captured maps, and prisoner interrogations. Flash-spotters and sound-rangers just could not keep up.[193] McNaughton reformed the observation section in the Canadian Corps to suit the demands of mobile warfare by reducing the number of sound-ranging sections and giving wireless sets to flash-spotters.[194]

The efficiency of the Canadian Corps CBO and its programmes during the Hundred Days does not wholly explain the general ineffectiveness of German indirect fire. After the Second Battle of the Marne (15 July – 6 August 1918) and Amiens, the German high command became concerned over their gun losses and pulled their field artillery back, which made their pieces less vulnerable to counter-battery fire and easier to withdraw.[195] But, siting their guns farther back meant that they could not target infantry advancing through their forward defensive zone. Plus, German artillery ammunition stockpiles ran low in 1918, and the artillery had strict engagement criteria to conserve ammunition and avoid being detected by the Allies.[196] In one instance, the intelligence officer corroborated the claims of captured German gunners that they were low on ammunition with a captured map that had the locations of 600 British gun positions

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[188] Schreiber, *Shock Army of the British Empire*¸ 44.
[189] Nicholson, *Official History of the Canadian Army in the First World War*, 555-556.
[190] Nicholson, *The Gunners of Canada*, 367.
[191] Marble, *British Artillery on the Western Front in the First World War*, 241.
[192] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 7, File 10, CBO, C.B. 18/4-4, "Organization and Procedure of the Counter-Battery Staff Office," 25 January 1919; LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 7, File 10, Canadian Corps, B.M. 140/205, "Discussion of Evidence as to the Organization of Heavy Artillery for an Imperial Army," 2, 3 April 1919; and Nicholson, *The Gunners of Canada*¸ 367.
[193] Innes, *Flash Spotters and Sound Rangers*, 84, 147.
[194] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 5, 6-7, 17 January 1963.
[195] Strong and Marble, *The Artillery in the Great War*, 153.
[196] Ibid, 187; and William Van der Kloot, "Lawrence Bragg's Role in the Development of Sound-Ranging in World War I," *Notes and Records of the Royal Society* Vol. 59, no. 3 (September 2005): 280.

plotted, but only twenty-two counter-battery engagements carried out.[197] Without sufficient shells, German defensive fire plans could neither last as long nor be as intense as they had been earlier in the war. The Germans could simply not engage the types of interdiction and counter-barrage fires that they practiced during the battles of the Somme and Passchendaele.

The Canadian Corps CBO adapted to the changes in battlefield conditions. The high tempo of operations and the inability to collect intelligence on the precise location and size of German artillery through sound-ranging and flash-spotting precluded the conduct of destructive shoots – a lesson captured in the report from Amiens. Predicted fire and neutralization became the preferred methods for counter-battery fire. Sometimes the Germans made it easier, oddly enough. Valenciennes was the exception to the German 1918 rule of positioning guns further back. At Valenciennes, they pushed their field artillery forward to maximize the range into the Anglo-Canadian depth. This positioning only made their guns easier to target. No registration or destructive shoots proceeded the counter-battery programme that began ten minutes before zero hour, 0515hrs 1 November.[198] They were not necessary. The fire plan neutralized known hostile batteries while aircraft or FOOs to called for fire on German guns and other high-payoff targets that the CBO had not previously identified, all to great effect.[199] These were all lessons learned at Amiens, and the report produced on Valenciennes explicitly mentioned this link.

Undoubtedly, McNaughton and the staff of the Canadian Corps CBO conducted operational research as we understand it today. He sought out civilian and military experts to help the Canadian Corps improve its detection techniques, particularly sound-ranging and flash-spotting (*innovation* and *trials*). Through *experimentation*, the corps had success with these innovative methods and mostly won the counter-battery fight in the battles of 1917 and 1918. And, finally, the Canadian Corps counter-battery organization could not have built such an effective system without the support of the chain of command, help from military and civilian experts, and adopting best practices from other formations in the BEF (*dissemination*).

[197] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3921, Folder 6, File 1, Reconnaissance Officer for GOC RA First Army, "Information Obtained from Captured German Counter-Battery Maps," 1 October 1918.
[198] LAC, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery, Vol. 3923, Folder 11, File 8, CBO, "Notes on Counter-Battery Support and Capture of Mont Houy by the Canadian Corps, 1 November 1918," 3-4, 3 February 1919.
[199] LAC, RG9-III-D-3, Vol. 4974, File 561, WD – Canadian Corps Heavy Artillery, 1 November 1918.

Chapter 2 – The Operational Research of Bullets and Gas

Before breaching the Canal du Nord (27 September 1918), one of the most audacious operations conducted by the Canadian Corps, Sir Arthur Currie reported, "A complete programme of harassing fire by Artillery and Machine Guns was also put in force nightly. The Corps Heavy Artillery... carried out wirecutting, counter-battery shoots and gas concentrations daily, in preparation for the eventual operations."[200] As Currie noted, the Canadian Corps did not only rely on artillery to shape the battlefield. Fire plans also incorporated indirect machine-gun fire and gas. Together they provided what one historian has compared to a "percussion crescendo" that supported the advance of the infantry.[201] While gunners had conducted the technique of indirect artillery fire since the late nineteenth century, armies did not use chemical warfare or indirect machine-gun fire on the battlefield until 1915. How did the Canadian Corps manage to incorporate gas and machine-gun barrages into its fires such that they enabled the infantry to break into the toughest German defensive positions? Moreover, how did the Canadian Corps protect its soldiers so that they could fight in a chemical environment?

In both instances, machine-gun and gas officers used the methodology of operational research to make these methods as effective and as efficient as possible. The BEF's experience on the Somme had resulted in the addition of machine-gun and gas staffs to the corps headquarters. Like the staff of the CBO, the staff officers of the Canadian Machine Gun Corps (CMGC) and the Canadian Corps Gas Services (CCGS) innovated, trialled, experimented, and disseminated their findings and best practices. Many staff officers leveraged their prewar scientific backgrounds and benefited from the innovations and practices of other formations in the BEF. Curiously, despite the importance of gas and machine guns to the fires of the Canadian Corps, neither arm had a robust staff structure comparable to the artillery. Nor did they have a prestigious office like the CBO with access to the corps commander. Insufficient staffing to manage both operations and operational research imposed limitations on the scientific work that these staff officers could conduct. And the nature of the weapon systems complicated data collection. Whereas the effects of artillery on the battlefield (cratering or damage from shrapnel) could be measured, the effects of gas or bullets fired during a machine-gun barrage could not be easily gauged. Personalities and inter-arm rivalries negatively affected the operational research done by gas and machine-gun officers as well. Despite these challenges, there is much evidence of operational research indicators – innovation, trials, experimentation, and dissemination of findings – however imperfectly they may have been done.

Armies had fielded variants of the machine gun since the American Civil War; however, the stature of the machine gun rose dramatically on the Western Front. In the BEF, machine guns eventually emerged as a distinct arm. In 1914, each infantry battalion in the CEF had just two machine guns.[202] As the number of machine guns in the Canadian Corps increased between 1915 and 1918, the corps first grouped all the heavy Vickers machine guns into companies that affiliated with brigades. These machine-gun units comprised the "best and brainiest men" from the infantry battalions.[203] The formation of the CMGC as a distinct arm from the infantry followed on 15 January 1917.[204] The last major reorganization occurred in May 1918 when the Canadian Corps reorganized the brigade machine-gun companies into divisional machine-gun battalions, each with ninety-six guns. Two motorized machine-gun brigades, with forty guns, augmented machine-gun barrages for corps operations. These reorganizations largely followed those implemented by the British Army, except in 1918, a Canadian division had ninety-six machine guns

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[200] Quoted in OMFC, *Report of the Ministry Overseas Military Forces of Canada*, 155.
[201] Schreiber, *Shock Army of the British Empire*, 47.
[202] Nicholson, *Official History of the Canadian Army in the First World War*, 25.
[203] H.T. Logan and M.R. Levey, *History of the Canadian Machine Gun Corps, C.E.F.* (Bonn, London, and Ottawa: Canadian War Narratives Section, 1919), 100. I am grateful to Dwight Mercer for providing me with this reference.
[204] LAC, RG9-III-D-3, Vol. 4981, File 598, WD – Corps Machine Gun Officer, Canadian Corps, November 1916 – June 1917, Appendix M, Canadian Corps General Staff, G. 669 61/21, "Memorandum to Form Canadian Machine Gun Corps," 15 January 1917.

to a British division's sixty-four.[205] Combined, the Canadian Corps had nearly the same firepower as a small British army. Not only quantitative differences existed between the CMGC and the British Machine Gun Corps. The commander of the CMGC also had greater control over these weapons, since GHQ did not uniformly implement this control for the corps machine gun commander across the BEF until November 1918.[206] Not only did Brutinel have more machine guns at his disposal, but he also had the command and staff structure to use them efficiently.

These Vickers machine guns fired indirect barrages. Machine gunners had some knowledge of indirect fire before the war, but, like the artillery, most understood their role to be primarily as a direct fire weapon.[207] Indirect fire, however, enabled the engagement of targets situated in defilade. It also enabled the machine guns to fire over the heads of advancing infantry and augment the fire plan. The actual procedure for indirect machine-gun fire mirrored the procedures used by the artillery. To fire indirect, the machine gunner needed to determine the following: the exact position of his weapon, the direction to the target, the distance between the gun and target, as well as the angle of sight between the gun and target.[208] When firing over friendly troops, machine gunners also needed to account for the distance from the gun position to friendly troops and the height of friendly troops above the gun position. The gunner determined direction and range with a compass and map, and then used a spirit level, elevating dial, or clinometer, an instrument that measures the angle of elevation of the barrel from the ground, to set the elevation of his gun. Machine-gun barrages adhered to the same principles of artillery barrages, but officers gave more consideration to siting the machine guns in enfilade to maximize the beaten zone of the weapon over the target during the barrage.[209]

The Canadian Corps incorporated machine-gun bullets into the wider fire plan prepared by the artillery. Captain George Lindsay, a British infantry officer in charge of machine gun training for the new armies, had pioneered the use of machine-gun barrages.[210] Lindsay's ideas shaped the experimentation with this technique on the battlefield that started in 1915, although the first instance of a machine-gun barrage is difficult to determine. The British official history states that the machine guns of the British 2nd and 47th (2nd London) Divisions fired the first indirect machine-gun barrage during the Battle of Loos.[211] However, historian Paddy Griffith writes, "the true father of the machine gun barrage turn out to have been the equally energetic and forceful Brigadier E. [*sic*] Brutinel, the machine gun officer to the Canadian Corps."[212] Griffith credits Brutinel with firing the first barrage on 2 September 1915. In neither case, however, was the machine-gun fire incorporated into the wider fire plan.

The myth of the superiority of Dominion forces over their British counterparts extends to the use of indirect machine-gun fire. Pierre Berton claims, "The British thought of the machine gun as a kind of super rifle. It took the Canadians to demonstrate at Vimy that it could be employed as light artillery."[213] Shelford Bidwell and Dominick Graham argue that the Canadian Corps pioneered machine gun tactics because its officers did not hold "prejudices" against employing the weapon in an indirect fire role like

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[205] Nicholson, *Official History of the Canadian Army in the First World War*, 383.
[206] Logan and Levey, *History of the Canadian Machine Gun Corps*, 150.
[207] R.V.K. Applin, *Machine-Gun Tactics* (London: Hugh Rees Ltd., 1910), 46-54.
[208] J. Bostock, *The Machine Gunners' Handbook: Including the Vickers and Lewis Automatic Machine Guns, Eleventh Edition* (London, W.H. Smith & Son, 1917), 197-198.
[209] General Staff, General Headquarters, *Notes and Rules for Barrage Fire with Machine Guns* (Machine Gun School, Machine Gun Training Centre, May 1917). The beaten zone refers to the elliptical shape formed when the rounds fired from the machine gun strike the ground or target.
[210] Griffith, *Battle Tactics of the Western Front*, 123-124.
[211] James E. Edmonds, *History of the Great War: Military Operations, France and Belgium, 1915, Volume II, Battles of Aubers Ridge, Festubert, and Loos* (London: His Majesty's Stationery Office, 1936), 188, 254.
[212] Griffith, *Battle Tactics of the Western Front*, 124.
[213] Berton, *Vimy*, 170.

the British Army did.[214] These arguments are unfounded. The BEF first incorporated a machine-gun barrage into the artillery plan during the attack on Thiepval Ridge (26-27 September 1916).[215] Incidentally, the Canadian Corps played a prominent role in this attack. The attack did not result in complete success, but the machine-gun barrage fired by the 1st Canadian Motor Machine Gun Brigade worked. "[I]t is reported that during the 1st hour of firing that [the machine-gun] Battery completely wiped out [the] German counter attack directed against the flank held by the 14th Batt[alion]."[216] Still, machine-gun barrages were not particularly efficient, and a machine gun company could fire well over one million rounds in a single day, all to produce more or a morale effect than a physical one.[217] Making machine-gun barrages more effective and efficient required operational research.

Raymond Brutinel played an instrumental role in the innovations of machine-gun tactics and methods. An engineer by trade and a French soldier when the war began, Brutinel enlisted in the CEF at the request of Sir Clifford Sifton, the former Canadian Minister of the Interior, to help form the 1st Canadian Motor Machine Gun Brigade.[218] Brutinel assisted in raising funds for its equipment, arranged for the design and purchase of their armoured cars, and purchased their first Colt machine guns.[219] He also promoted a culture of learning within the machine gun unit. In one early experiment, Brutinel instructed his staff to make a terrain model and plot the trajectories of the machine guns.[220] From this model, he determined that machine guns could fire indirectly 500 yards into the enemy's rear area, where several German artillery officers congregated at predictable times. After engaging and scattering these officers several times, the German artillery retaliated against the machine guns. Brutinel used their retaliation as proof that his indirect machine-gun fire methods worked. While this experiment lacked the rigour of later tests, it was a start.

Like Andrew McNaughton, Brutinel was an egotistical self-promoter. During the war, he disagreed or clashed with Lindsay, Secretary of State for War Lord Kitchener, Lieutenant-General E.A.H. Alderson, then commander of the 1st Canadian Division, Brigadier-General C. Bonham-Carter, Brigadier-General Staff (Training) at GHQ, and the staff of the GHQ Machine Gun School.[221] Generally, his disagreements with these people stemmed from his belief that they did not understand how machine guns ought to be employed. His tendency to take credit for almost all innovations in machine-gun tactics and techniques makes substantiating his claims difficult. For instance, he claimed that the French Army sought him out to instruct French officers on the machine-gun methods he had used at Vimy. Brutinel did lecture French machine-gun officers; however, his claim that General Émile Fayolle, commander of *Groupe d'armées du Centre*, watched Brutinel's demonstration, converted to his methods, and then ordered a commander to attack with only a machine-gun barrage supporting the advance seems unlikely.[222] The French official history makes no mention of Brutinel drastically revising French doctrine,

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[214] Bidwell and Dominick Graham, *Fire-Power*, 123.
[215] Farndale, *History of the Royal Regiment of Artillery*, 154.
[216] LAC, RG9-III-D-3 Vol. 4986, File 626, WD – 1st Canadian Motor Machine Gun Brigade, September 1916, Appendix 137, Lieutenant-Colonel Raymond Brutinel, "Report on Operation 26-27 September 1916," n.d.
[217] Griffith, *Battle Tactics of the Western Front*, 124.
[218] LAC, RG150, Accession 1992-93/166, Box 1212-39, Raymond Brutinel Personnel File; and Canadian War Museum (CWM), George Metcalf Archival Collection, 20020045-1525, "The Raymond Brutinel Tapes," Tape 1, 2, 18 October 1962. I am grateful to Dwight Mercer for providing me with this reference.
[219] Logan and Levey, *History of the Canadian Machine Gun Corps*, 16.
[220] CWM, George Metcalf Archival Collection, 20020045-1525, "The Raymond Brutinel Tapes," Tape 11, 2, 18 October 1962.
[221] CWM, George Metcalf Archival Collection, 20020045-1525, "The Raymond Brutinel Tapes," Tape 7, 1-2; and Tape 21, 1-2, 18 October 1962.
[222] CWM, George Metcalf Archival Collection, 20020045-1525, "The Raymond Brutinel Tapes," Tape 20, 3, 18 October 1962.

and Fayolle had established a reputation for meticulous artillery preparations before his attacks.[223] During the summer of 1917, the French Army was in a state of mutiny after the failed Nivelle offensive, so it seems unlikely that any commander would have ordered an attack without artillery support.

The CEF had its debut with chemical warfare during the Second Battle of Ypres, when the German Army used chlorine gas against the soldiers of the 1st Canadian Division as well as the French *45e division d'infanterie* and *87e division d'infanterie territoriale.* Neither the Canadians nor the French had protection against the new weapon. Innovation had to occur to shield their forces from the effects of poison gas. Much like early flash-spotting and sound-ranging innovations, serving officers with a scientific background identified the problem and proposed solutions almost immediately. The ammonia in urine partially neutralized chlorine, so when the German unleashed gas against the Canadian division on 24 April 1915, several officers ordered their soldiers to urinate in their handkerchiefs and cover their faces with the cloths.[224] Better solutions followed. Both the gas and medical services of the BEF began developing masks and respirators to protect their soldiers from the physical effects of gas and enable them to fight in a chemical environment. The War Office experimented with several gas mask designs before adopting the small box respirator in August 1916.[225] This gas mask remained in service for the remainder of the war. Even with this mask, though, the CCGS and Canadian Army Medical Corps (CAMC) had to continually revise training and techniques to mitigate against newer, deadlier gases delivered through increasingly effective means. The fight against gas never ceased.

Like all weapons, gas also has psychological as well as physical effects, and the morale effect of it amplifies when used against undisciplined or ill-trained soldiers. Soldiers needed to know that their respirators worked and how to use them. Gas training became as necessary as rifle shooting and grenade throwing. Historian C.R.M.F. Cruttwell, who served as an officer with the 1/4th Battalion, Royal Berkshire Regiment, described the soldiers' predicament.

> In the face of gas, without protection, individuality was annihilated; the soldier in the trench became a mere passive recipient of torture and death…. [N]early every soldier is or becomes a fatalist on active service; it quietens his nerves to believe that his chance will be favourable or the reverse. But his fatalism depends upon the belief that he has a chance. If the very air which he breathes is poison, his chance is gone: he is merely a destined victim for the slaughter. Later on, when gas-masks became increasingly efficient, this type of warfare was regarded as an unpleasant incident, for suffering became contingent on carelessness or surprise.[226]

Historian Tim Cook expanded upon this concept of "belief" in equipment: "The creation of the faith in both respirators and anti-gas training was the most important legacy of the Canadian Corps Gas Services."[227] Measuring faith is impossible, and faith is rarely rooted in fact. Yet in the case of chemical warfare, faith still needed science.

Trialling completed during training in France was vital to this process. After witnessing one such gas mask trial in May 1915, a soldier wrote, "We were at first rather skeptical as to their efficiency, but

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[223] Ministère de la guerre, état-major de l'armée – service historique, *Les Armées Françaises dans la Grande Guerre, Tome V, Volume 2: Les offensives à objectifs limités, 15 mai – 1 novembre 1917* (Paris: Imprimerie nationale, 1937), 340; and Robert A. Doughty, *Pyrrhic Victory: French Strategy and Operations in the Great War* (Cambridge and London: Harvard University Press, 2005), 291-292.
[224] Cook, *No Place to Run*, 6-7.
[225] Nicholson, *Official History of the Canadian Army in the First World War*, 71.
[226] C.R.M.F. Cruttwell, *A History of the Great War, 1914-1918* (Oxford: Clarendon Press, 1934), 153-154.
[227] Cook, *No Place to Run*, 233.

the *test* proved this to us and gave us a great deal of confidence."[228] Not all gas training proved as beneficial, and some formations went to the frontline inadequately prepared for the chemical environment.[229] The process of protecting soldiers from this new weapon was hardly perfect. However, gas training reinforced to soldiers the importance of gas discipline and gave them confidence in their protective equipment. Gunner G.H. Jackson described the gas training that he underwent in France. "[T]he gas … turned my brass buttons black, destroyed the illuminated dial on my watch and turned my khaki uniform a reddish brown. Say! what [*sic*] would it do to your lungs without protection?"[230] No training could ever fully prepare a soldier for combat. However, any training is better than none, and gas staffs used operational research – especially trialling – to develop protective equipment and training to protect BEF soldiers from the effects of chemical warfare.

The BEF did not only develop countermeasures to gas; it actively sought to use gas offensively. In June 1915, the War Office formed two Special Companies, Royal Engineers that comprised soldiers and officers with chemistry backgrounds and appointed a Royal Engineer officer, Major C.H. Foulkes, to conduct and coordinate chemical warfare in the BEF.[231] Eventually, this force expanded into the Special Brigade, Royal Engineers. The Special Brigade used a variety of delivery systems to attack the Germans with gas. It was the only force in the BEF that used gas offensively until the artillery received large quantities of gas shells in 1917. The British first used gas on a large scale at Loos. In planning the attack, Douglas Haig, then commander of First Army, opted to use dispensed chlorine gas to compensate for the insufficient quantity of guns and shells.[232] Despite some successes, the gas failed to subdue the German defenders, and the attack resulted in minimal gains with heavy casualties. After the battle, Foulkes ordered his officers to submit notes on the results of the chemical attacks, assessing the effectiveness of the gas in their sectors. He also compiled reports from captured German documents and prisoners.[233]

By analyzing these notes and reports, Foulkes quantified the effects of gas and developed the procedures for the proper use of gas. This problem solving is what operational research does, finding shortcomings in the system and addressing them to improve effectiveness and efficiency. Still, the gas officers needed to integrate gas into the overall fires system. Arguments proposed by historians like James Edmonds, the British official historian of the Great War, that "Gas achieved but local success, nothing decisive; it made war uncomfortable, to no purpose" miss the mark.[234] Donald Richter's assertion that chemical warfare was "occasionally effective, never decisive" is probably more balanced.[235] Like aircraft, machine guns, and quick-firing artillery, it could never win the war on its own, but when combined with artillery and machine guns, it did help achieve neutralization and suppression effects.

As the employment of gas and machine guns required increasingly specialized skills, the staff establishment responsible for their use grew. A First Army order to the Canadian Corps in the spring of 1916 appointed a gas officer (DGO) in each divisional headquarters and effectively created the CCGS.[236]

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[228] Quoted in Richter, *Chemical Soldiers*, 13. Emphasis added by the author.
[229] Cook, *No Place to Run*, 81, 90-94.
[230] Charles Lyons Foster and William Smith Duthie, eds., *Letters from the Front: Being a Record of the Part Played by Officers of the Bank in the Great War, 1914-1918, Volume I* (Toronto and Montreal: Southam Press Limited, 1920), 149.
[231] Palazzo, *Seeking Victory on the Western Front*, 44; and Richter, *Chemical Soldiers*, 16.
[232] Edmonds, *History of the Great War: Military Operations, France and Belgium, 1915, Volume II*, 153.
[233] Richter, *Chemical Soldiers*, 92.
[234] James E. Edmonds, *History of the Great War: Military Operations, France and Belgium, 1918, Volume V, 26 September-11 November: The Advance to Victory* (London: His Majesty's Stationery Office, 1947), 606n2
[235] Richter, *Chemical Soldiers*, 147.
[236] William G. Macpherson, *History of the Great War: Medical Services, Diseases of the War, Volume II, Including the Medical Aspects of Aviation and Gas Warfare, and Gas Poisoning in Tanks and Mines* (London: His Majesty's Stationery Office, 1923), 328-334.

And the formation of the CCGS helped ensure uniformity of anti-gas training across the divisions of the corps.[237] It also facilitated the dissemination of lessons learned within the Canadian Corps and to other British formations. By October 1916, battalions, brigades, and divisions all had gas officers, who were responsible for anti-gas training and adherence to regulations. Only the corps lacked a gas officer. Like the artillery, the gas services operated within a wider imperial structure, and these innovations to the Canadian chemical warfare establishment largely resulted from the British direction. The British had grouped their offensive and defensive chemical warfare specialists under the Gas Services on 25 January 1916.[238] This directorate coordinated both offensive and defensive aspects of chemical warfare. Efforts to create Canadian Engineer "Special Companies," responsible for the offensive use of gas during the winter of 1917-1918, did not materialize.[239] Thus the CCGS played the largest role in the development of anti-gas techniques and advised on the offensive use of gas.

The emergence of the CMGC as a distinct arm from the infantry facilitated the conduct of operational research by machine-gun officers. Like McNaughton, Brutinel enjoyed the support of the senior commanders in the Canadian Corps and the BEF for his work. Haig was even enthusiastic about the technique.[240] Brutinel's forceful personality may have brought him into conflict with others, but it also ensured that the CMGC could maintain the corporate knowledge of indirect fire.[241] Otherwise, its officers would lose the necessary skillsets for this technical work. Brutinel recalled:

> To maintain the fluidity of this great fire power, intense training was essential, implying tactical appraisal of the task at hand, the Machine Gun Officer becoming ipso facto the Technical Adviser of the Infantry Commander, or if preferred, his Consulting Engineer. The Administrative organization of the Canadian Machine Gun Battalion met these essentials.[242]

The machine gunners adopted a unique organization structure in much the same way the artillery did. Not only did this unified structure improve standardization in the training and use of machine guns, but it also facilitated the control of corps-level machine-gun barrages and the dissemination of new ideas and innovations from the machine-gun units to the headquarters of the Canadian Corps.

The General Officer Commanding (GOC) CMGC had a modest staff that included a brigade major for operations, a staff captain for administration and transport, a reconnaissance officer, and seven other ranks (see figure 2.1). The brigade major, Major W.B. Forster, had worked as an accountant before the war and attested into the 27th Canadian Infantry Battalion.[243] The officer responsible for administration, Captain J.K. Lawson, had a prewar administrative career.[244] The reconnaissance officer, Lieutenant W.T. Trench, and his replacement from 24 April 1918, Lieutenant P.M. Humme, had both worked as surveyors.[245] Levey, the officer who had collected data from the early trial, joined the staff as a

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[237] Cook, *No Place to Run*, 6-7.
[238] James E. Edmonds, *History of the Great War: Military Operations, France and Belgium, 1916, Volume I, Sir Douglas Haig's Command to the 1st July: Battle of the Somme* (London: His Majesty's Stationery Office, 1932), 78.
[239] Cook, *No Place to Run*, 143.
[240] Sheffield, *The Chief*, 151.
[241] Logan and Levey, *History of the Canadian Machine Gun Corps*, 45.
[242] CWM, George Metcalf Archival Collection, 20020045-1525, "The Raymond Brutinel Tapes," Tape 9, 2, 18 October 1962.
[243] LAC, RG150, Accession 1992-93/166, Box 3212-14, William Burton Foster Personnel File.
[244] LAC, RG150, Accession 1992-93/166, Box 5471-20, John Kilburn Lawson Personnel File.
[245] LAC, RG150, Accession 1992-93/166, Box 9777-69, Waldo Talbot Trench Personnel File; and LAC, RG150, Accession 1992-93/166, Box 4609-48, Powell Mat Humme Personnel File.

staff learner during the summer of 1918.[246] The combined mathematical and administrative abilities of the staff were well suited the conduct of operational research. Each infantry division commander retained authority over the machine-gun battalion affiliated with their division. However, the GOC CMGC assumed control to coordinate machine-gun plans for corps-level battles. Planning these barrages required much staff effort, and they conducted most of their research during operational lulls. While the formation of gas and machine-gun staffs helped the Canadian Corps better use these weapons, neither the CCGS nor the CMGC had a large staff complement that could manage operations and conduct operation research like the CBO could do. The corps headquarters did not permanently allocate staff supporting the corps machine gun officer until 19 March 1918.[247]

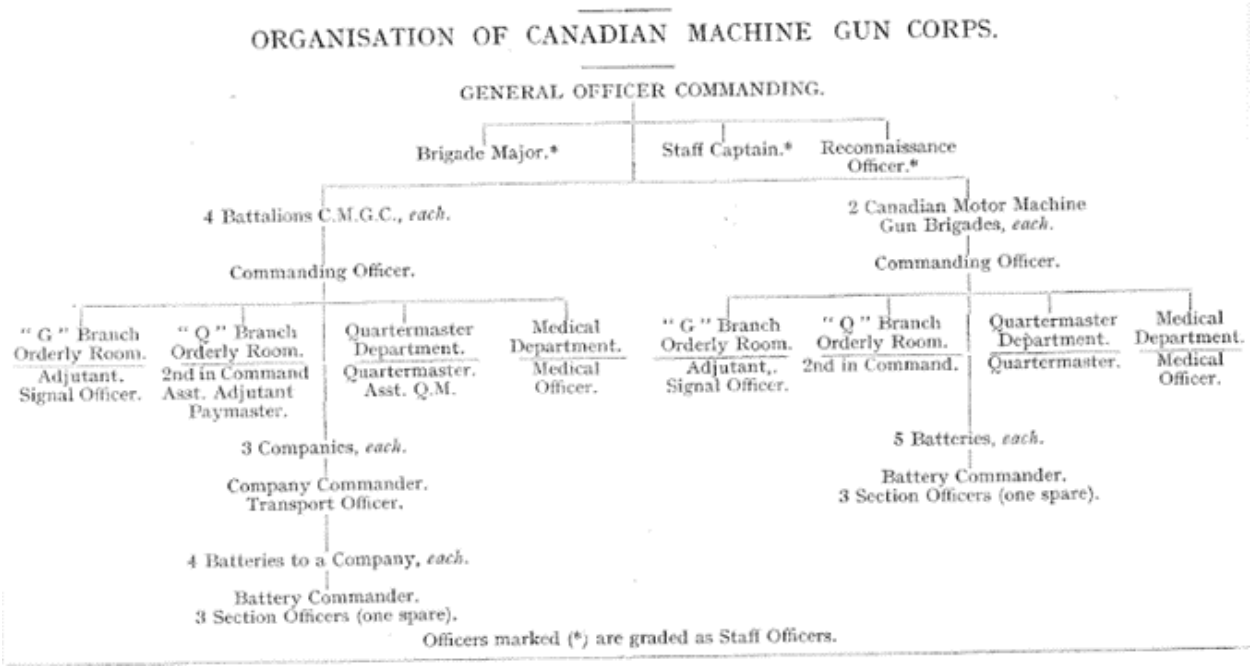

Figure 2.1 Organization and Staff Structure of the Canadian Machine Gun Corps, 1918
Source: OMFC, *Report of the Ministry Overseas Military Forces of Canada, 1918* (London: His Majesty's Stationery Office, 1919), 290.

The formation of a staff to manage chemical warfare at the corps level did not occur until 1917, and the gas services staff lacked sufficient personnel to manage its myriad responsibilities. On 26 March 1917, the Canadian Corps appointed Captain W. Eric Harris as the chemical advisor in the corps headquarters.[248] The chemical advisor billet fell under the purview of the "G" or operations staff. However, his close liaison with the CAMC, training establishments, and logistics organizations meant he also had close links with the corps "A" (personnel) and "Q" (logistics) staff. The small staff that comprised the CCGS included a clerk, corporal, batman, and driver.[249] As the corps chemical advisor, Harris leveraged the DGOs as well as the brigade and battalion gas officers for data for analysis that he integrated into his operational research reports (see figure 2.2). However, he only had coordination authority with these officers. This limited command arrangement denied Harris the flexibility to modify

[246] LAC, RG150, Accession 1992-93/166, Box 5611-79, Mark Robert Levey Personnel File. On the staff learner system in the Canadian Corps, see Delaney, "Mentoring the Canadian Corps." 942-943.
[247] Logan and Levey, *History of the Canadian Machine Gun Corps*, 65.
[248] LAC, RG150, Accession 1992-93/166, Box 4097-44, Walter Eric Harris Personnel File.
[249] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, April 1917, Appendix II, First Army Headquarters, "Establishment of the Gas Services," 12 February 1917.

the structure and manning of the corps gas staff based on operational experience, something McNaughton never had to worry about with the CBO. Furthermore, Harris did not have the same authority over the DGOs that McNaughton had over the guns of the heavy artillery, despite the neat organizational diagram at figure 2.2. Harris could only do so much work with his tiny staff, and he even had difficulty maintaining the CCGS war diary.[250]

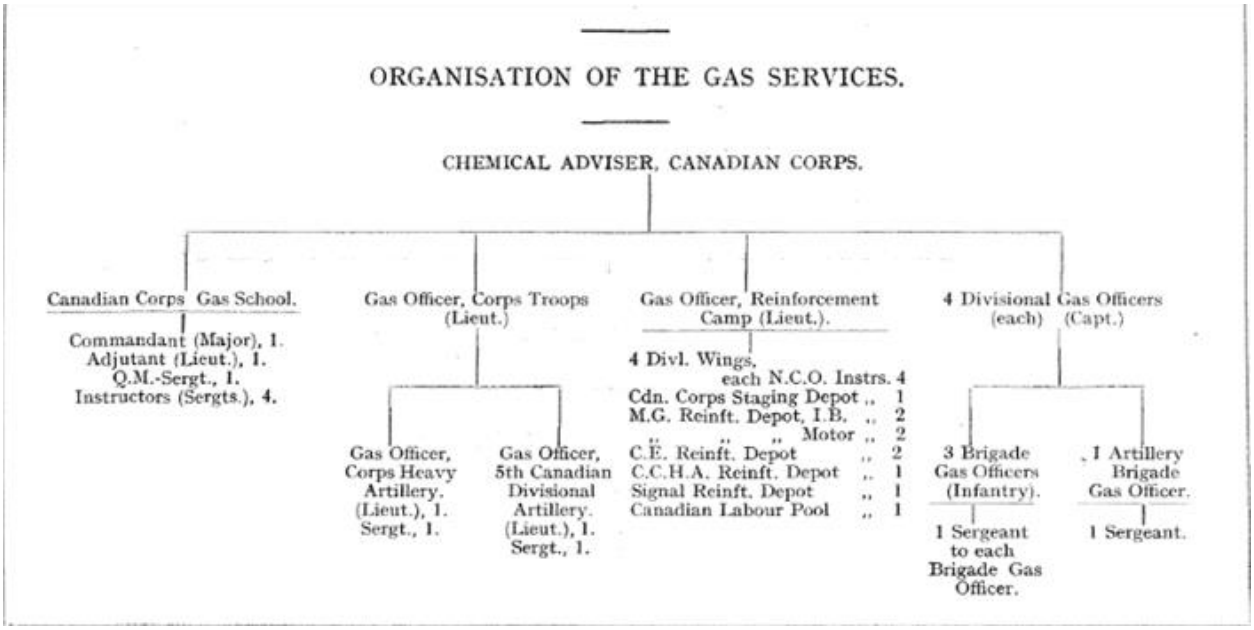

Figure 2.2 Organization and Staff Structure of the Canadian Corps Gas Services, 1918
Source: OMFC, *Report of the Ministry Overseas Military Forces of Canada, 1918* (London: His Majesty's Stationery Office, 1919), 283.

Since armies only began using chemical weapons on a large scale during the First World War, the War Office had to look beyond formal military training to find suitable officers for service on the chemical warfare staff. These gas officers had a long list of responsibilities, and the army attempted to match their relevant qualifications and skills from their prewar civilian careers to their new military duties. Principally, Harris was responsible for the coordination and training of the DGOs as well as the standardization of the corps anti-gas policy.[251] Other important tasks included liaison with the artillery for the use of gas shells, collation of information on German chemical warfare tactics from prisoner of war interrogations, and collection of samples of new chemical agents used by the Germans for the British Gas Services to analyze. His prewar career as a science teacher helped with these tasks.[252] Harris had joined the CEF as an artillery officer but mostly served as a gas officer, first with the 2nd Canadian Division and later as the assistant chemical advisor at First Army. All the DGOs in the Canadian Corps in April 1917 also had scientific, teaching, and administrative backgrounds. Lieutenant A.A. McQueen, 1st Canadian Division DGO, worked as an electrical engineer before he enlisted into the artillery.[253] Lieutenant A.B. Campbell, 2nd Canadian Division DGO, an infantry officer, had been a clerk.[254] The DGO of the 3rd and 4th Canadian Divisions, Lieutenants N.C. Qua and H. Beaumont, worked in education and mining,

[250] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, August 1917, Canadian Section GHQ, "Note to Canadian Corps Chemical Advisor," 28 September 1917.
[251] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, April 1917, Appendix I, First Army Headquarters, No. G.S. 528 "Duties of the Chemical Advisor," 11 March 1917.
[252] LAC, RG150, Accession 1992-93/166, Box 4097-44, Walter Eric Harris Personnel File.
[253] LAC, RG150, Accession 1992-93/166, Box 7193-9, Allan Alderson McQueen Personnel File.
[254] LAC, RG150, Accession 1992-93/166, Box 1419-28, Alexander Bruce Campbell Personnel File.

respectively.[255] The staff of the CCGS understood the components of systems, as well as the importance of learning and administration. Innovating, trialling, experimenting, and disseminating – the hallmarks of operational research – required these skill sets.

The findings of the operational research performed by Harris and his staff percolated through the army headquarters to GHQ and were finally encapsulated in doctrine, such as *SS534 Defence Against Gas*.[256] In cooperation with the CAMC, the CCGS conducted a rigorous programme of operational research to defend against poison gas. For instance, in September 1917, the CCGS examined no fewer than six areas of concern, including countermeasures for new German gas shells, testing sites to determine the efficacy of gas masks, and an increase in casualties suffering temporary blindness from exposure to mustard gas.[257] Following an enemy gas shell bombardment against the battery positions of the 2nd Canadian Divisional Artillery on 6 September 1917, the gas officer investigated the types of ammunition fired, recorded the prevailing meteorological conditions, interviewed the casualties, and noted the state of the gas-proof dugouts.[258] He found that the Germans fired a mixture of high-explosive and gas shells to damage the gas-proof dugouts and target exposed soldiers with both splinters and gas. The batteries had taken additional precautions prior to the shelling owing to the favourable conditions for a gas bombardment. The Canadian gunners sustained two serious casualties, one caused by a splinter from high explosive and the second from the force of the gas shell bursting on top of the gun pit. No serious casualties were attributed to the gas itself. The gas officer attributed the lack of casualties to the effectiveness of the gas-proof dugouts and the small box respirator. He made minor recommendations for additional procedures, such as increased vigilance during weather conditions favourable to a gas bombardment and limiting the frequency that personnel moved in and out of the gas-proof dugouts during a bombardment, and presented his findings in a report submitted to Harris on 10 September. Harris discussed the report at a conference with the DGOs on 15 September and forwarded it the chemical advisor at First Army headquarters.[259] While the report went up, Harris issued a new directive on 1 October for defensive measures against gas for artillery units in the Canadian Corps.[260] The directive addressed all of the recommendations from the 6 September bombardment.[261] The CCGS sent copies of these reports and directives to the chemical advisor at the First Army headquarters, which compiled the reports from its corps and sent a consolidated report to GHQ. The British Gas Services at GHQ analyzed these reports and eventually published pamphlets like *SS534*.[262] These publications spurred further operational research to verify the effectiveness of new methods, and the cycle of operational research began again.

While the CCGS did not have a monopoly on trialling, it was the only organization in the Canadian Corps that committed the findings of its trials to paper and disseminated them. The infantry conducted some creative trialling with chemical defence, but tests conducted outside of the formal

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[255] LAC, RG150, Accession 1992-93/166, Box 8039-3, Norman Charlton Qua Personnel File; and LAC, RG150, Accession 1992-93/166, Box 563-32, Henry Vincent Leeming Beaumont.
[256] General Staff, General Headquarters, *SS534 Defence Against Gas* (March 1918).
[257] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, 1, 8, 10, 24, 25, and 27 September 1917.
[258] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, September 1917, Appendix I, Lieutenant H.H. Wallace, Artillery Gas Officer, 2nd Canadian Divisional Artillery "Report on Gas Shell Bombardment 2nd Canadian Divisional Artillery Battery Positions on September 6th, 1917," n.d.
[259] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, September 1917, Appendix II, "Minutes of Meeting of D.G.O.'s at C.A.'s Office Canadian Corps 15th September, 1917," 2, n.d.
[260] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, October 1917, Appendix I, "Defensive Measures Against Gas for Artillery Units," n.d.
[261] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, 10, 13, and 17 September 1917.
[262] General Staff, General Headquarters, *SS534 Defence Against Gas* (March 1918).

structure could never amount to much. "The other day we dug a deep trench and filled it with the brand of gas the Germans use; some of our boys put on a new style of [gas] helmet we have and walked through it. The test was highly satisfactory, so we have not much to fear."[263] While this test may have made the infantrymen confident in their respirators, these informal experiments lacked the rigorous data collection that typified reports prepared by the CCGS. The gas staff structured their reports on casualties like No. 2 ORS did in its reports on infantry casualties during the Normandy campaign.[264] Through these efforts, the Canadian Corps disseminated its findings with other formations and achieved high standards of gas discipline and training, which resulted in fewer gas casualties. General Sir Henry Horne, commander of First Army, sent a congratulatory letter to the Canadian Corps after it sustained less than forty casualties after a forty-eight-hour chemical bombardment attack in February 1918.[265] His letter noted how the effectiveness of the gas training and discipline in the corps contributed to this low figure of casualties. Achieving this high standard was not accident. It was the result of much deliberate work.

While being responsible for gas training allowed the staff of the CCGS to trial new masks and anti-gas drills, it also proved a distraction from operational research. As the chemical advisor to the Canadian Corps, Harris had control over all anti-gas training that corps schools conducted in France. However, his authority did not extend to the anti-gas training given to CEF recruits across the Channel. Furthermore, unlike Brutinel, Harris lacked the clout to make substantive changes to the CEF chemical warfare organization, which would have improved training. Following his appointment as commander of Canadian forces in the United Kingdom in December 1916, Lieutenant-General Sir Richard Turner improved the overall quality of training for Canadian soldiers in England; however the chemical defence training that recruits underwent there remained deficient.[266] Harris travelled to Britain in December 1917 to standardize the anti-gas training conducted there with that done in France and to form a chemical warfare training organization subordinate to the CCGS.[267] Harris struck out, and for the remainder of the war, gas training in England remained inadequate.[268] Navigating the relationship between the Canadian Corps and the Canadian forces in the United Kingdom remained a distraction for the CCGS. Harris and his staff spent an inordinate amount of time and effort sorting out training deficiencies of the replacements arriving from England instead of conducting research.

Brutinel and his staff did not invent indirect machine-gun fire. However, their innovations and trials resulted in the incorporation of machine-gun barrages into every corps fire plan after the Somme. The CMGC developed ballistic shooting cards by arcing the machine-gun fire on hard-packed sand beaches at low tide.[269] One of Brutinel's officers, Captain M.R. Levey, a surveyor before the war, measured the accuracy and precision of the bursts and cross-indexed the findings with their clinometers.[270] Trials like this one enabled the CMGC to accurately fire hundreds of thousands of bullets into pre-determined kill zones on order. This type of fire denied the Germans the opportunity to repair

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[263] Foster and Duthie, eds., *Letters from the Front*, 50.
[264] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, March 1918, Appendix 15, Major W.E. Harris, "Report on Recent Cases of Gas Casualties," 16 March 1918; and Copp, ed., "Report No. 19 Infantry Officer Casualties," in *Montgomery's Scientists*, 425-430.
[265] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, February 1917, Appendix 12, First Army Headquarters, No. G.S. 1035, "Letter of Appreciation of the High Standard of Discipline and Gas Training in the Canadian Corps," 19 February 1918.
[266] William F. Stewart, *The Embattled General: Sir Richard Turner and the First World War* (Montreal, Kingston, London, and Chicago: McGill-Queen's University Press, 2015), 171-206; and Cook, *No Place to Run*, 117.
[267] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, 22 December 1917.
[268] Harris subsequently had to leave France and return to England to supervise training on at least one other occasion. LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, 10 June 1918.
[269] CWM, George Metcalf Archival Collection, 20020045-1525, "The Raymond Brutinel Tapes," Tape 9, 2-3, 18 October 1962.
[270] LAC, RG150, Accession 1992-93/166, Box 5611-79, Mark Robert Levey Personnel File.

damaged obstacles and defensive positions at night and proved useful for cutting off German forces attempting to withdraw.[271] Much like the informal sharing of reports between artillery staffs, the machine-gun officers disseminated the results of this trial with other formations. It took many trials like this one, but eventually, training institutions adopted these methods and ensured standardization across the BEF. The involvement of Brutinel in these technical machine-gun innovations stands in marked contrast to Major-General E.W.B. Morrison and the development of the artillery. The latter preferred to let his talented subordinates like Alan Brooke and McNaughton do most of the work.

After the Somme, the Canadian Corps incorporated machine-gun barrages into all its major attacks. From these operations, Brutinel and his staff conducted much operational research to improve the effectiveness of their technique. The machine-gun barrage was an important component of the fire plan for the assault on Vimy Ridge, and Brutinel's guns fired nearly five million rounds during the barrage.[272] It prevented Germans from maintaining their defensive positions, and it augmented the suppression provided by the artillery barrage. Indirect machine-gun fire also prevented defenders from withdrawing or reinforcing their positions.[273] The report prepared after Vimy Ridge by the CMGC is interesting for how it contrasts with the one prepared by McNaughton and the staff of the CBO for the same battle.[274] The CBO conducted post-battle reconnaissance of the German battery positions to verify the accuracy of the intelligence and collect data on the effect of the counter-battery programme for statistical analysis. The CMGC staff relied largely on anecdotal evidence from machine-gun companies, infantry formation staffs, and prisoner interrogations – not quite the same quantitative rigour. Even so, the report still yielded several lessons learned.[275] Based on the evidence gathered, the morale effect of indirect machine-gun fire was more significant than the number of casualties inflicted on the Germans. That is what prisoners of war said, and the disrepair of obstacles and defensive position, German soldiers dared not enter for the machine-gun bullets raining down, corroborated it. So did the capture of trench mortar positions that had not been resupplied with ammunition. The report also recommended observation of fire, when possible, more clinometers (one per two machine guns), and an increase in the strength of the machine-gun companies to help carry the vast quantities of ammunition required to fire these barrages. The CMGC widely disseminated the report throughout the BEF and French Army, and *SS192*, *SS201*, and *Notes and Rules for Barrage Fire with Machine Guns* reflect several of its recommendations.[276] The staff also published a document on the employment of mobile forces based on the experiences of Brutinel's motorized machine-gun forces at Amiens and Arras.[277]

The machine-gun barrage supporting the attack on Valenciennes demonstrates that the CMGC adopted many of these findings. In addition to the overwhelming artillery preparations planned by McNaughton, forty-seven machine guns supported the attack of the 10th Canadian Infantry Brigade on

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[271] General Staff, General Headquarters, *SS201 Tactical Summary of Machine Gun Operations No. 1* (France: Army Printing and Stationery Services, October 1917), 2; and General Staff, General Headquarters, *SS192 The Employment of Machine Guns: Part I, Tactical* (France: Army Printing and Stationery Services, January 1918), 17.
[272] LAC, RG9-III-D-3, Vol. 4957, File 503, WD – GOC RA, Canadian Corps, April 1917, Appendix I, BGGS Canadian Corps, G.3. S.156/31/2., "Artillery Instructions for the Capture of Vimy Ridge," 3, 28 March 1917; and Logan and Levey, *History of the Canadian Machine Gun Corps*, 169.
[273] CWM, George Metcalf Archival Collection, 20020045-1525, "The Raymond Brutinel Tapes," Tape 19, 2, 18 October 1962
[274] LAC, RG9-III-D-3, Vol. 4981, File 598, WD – Corps Machine Gun Officer, Canadian Corps, November 1916 – June 1917, Appendix K, "Notes on the Employment of Machine Guns in the Canadian Corps during the Operations Leading to the Capture of Vimy Ridge," n.d.
[275] Ibid, 2, 8-9.
[276] General Staff, *SS201 Tactical Summary of Machine Gun Operations No. 1*; General Staff, *SS192 The Employment of Machine Guns*; and General Staff *Notes and Rules for Barrage Fire with Machine Guns*.
[277] LAC, RG9-III-D-3, Vol. 4817, File 19, WD – Canadian Corps – General Staff, September 1918, Appendix II. Canadian Corps General Staff, G.528/3-53, "*Employment of Corps Mobile Troops*," 2, 19 September 1918.

Mont Houy alone.[278] The machine guns fired the barrage with enfilading fire, and machine-gun officers were supposed to observe the fire and make modifications to the fire plan if necessary. Poor visibility and mist made observation impossible, so the machine guns fired the barrage in accordance with the scheduled timings.[279] The GOC CMGC praised the work of his machine gunners, and the history of the machine gun corps noted the "abundant evidence of the effectiveness of our Machine Gun Barrage."[280] However, with thousands of shrapnel, high explosive, and gas shells also being fired at the Germans, quantitatively assessing the effectiveness of machine-gun bursts was almost impossible. McNaughton, for instance, argued, "There is no evidence to show that the machine-gun barrage was very effective. We must not distort history to carry forward wrong conclusions as to the proper use of this important weapon."[281] Like Vimy, after-action assessments of the machine-gun barrage relied on anecdotal evidence – not statistics.[282] Only so much operational research could be conducted without data to substantiate or disprove the hypothesis that machine-gun barrages were effective.

Harris had to develop offensive gas procedures for the Canadian Corps. Before the widespread introduction of gas shells, only the Special Brigade, which was controlled by GHQ, had the equipment to disperse gas.[283] However, an increased supply of gas shells in 1917 meant that artillery played an increasingly important role in targeting the Germans with gas.[284] Earlier operations supported by gas had yielded mixed results. The 4th Canadian Division launched a four-battalion raid against a portion of Vimy Ridge on 1 March 1917.[285] The canister dispensed gas completely failed to subdue the German defenders, and the raid ended in disaster. The BEF had hard learned this lesson at Loos, but there is no evidence that the DGO, Lieutenant H. Beaumont, objected to a plan that completely relied on gas. The Canadian Corps appointed Harris to the headquarters later that month, and the corps never again launched attacks that depended on canister-dispersed gas to support the infantry.

Despite the disappointing results of the gas that supported the raid launched by the 4th Canadian Division, the Canadian Corps increasingly used gas in its operations but as part of the wider fires system that included the artillery, and machine guns. Within a fortnight of his appointment as the corps chemical advisor, Harris met with McNaughton to discuss the use of gas shells for the attack against Vimy Ridge.[286] While weather conditions precluded the use of gas as part of the fire plan on 9 April, the CCGS produced a thorough report on the plan for the chemical bombardment and subsequent use of gas shells during the battle (see appendix B, page 68).[287] Although weather affected artillery-dispersed gas less than it did canister-dispersed gas, high wind would still quickly dissipate an artillery-dispersed gas cloud.

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[278] LAC, RG9-III-D-3, Vol. 4986, File 624, WD – 4th Canadian Machine Gun Battalion, October 1918, Appendix Y, General Staff 4th Canadian Division, G. 29/2910-559, "Valenciennes Instructions No. 2," 4, 31 October 1918.
[279] LAC, RG9-III-D-3, Vol. 4986, File 624, WD – 4th Canadian Machine Gun Battalion, November 1918, Appendix G, Commanding Officer 4th Canadian Machine Gun Battalion, "4th Battalion Canadian Machine Gun Corps Report on Operations, 14 October to 6 November 1918," 1, n.d.
[280] Logan and Levey, *History of the Canadian Machine Gun Corps*, 422.
[281] Quoted in Swettenham, *McNaughton*, 153n1.
[282] Logan and Levey, *History of the Canadian Machine Gun Corps*, 422.
[283] Palazzo, *Seeking Victory on the Western Front*, 78-79.
[284] Ibid, 164-164.
[285] LAC, RG9-III-D-3, Vol. 4859, File 159, WD – 4th Canadian Division – General Staff, March 1917, Appendix A, Brigade Major 12th Canadian Infantry Brigade, S.G. 4/279, "Report on Operations Carried out by the 12th Canadian Infantry Brigade (In Conjunction with the 11th Canadian Brigade) on 1 March 1917," 5 March 1917.
[286] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, 7 April 1917.
[287] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, "Notes on Artillery preparation and Support of the Attack on Vimy Ridge. April 9th.1917," Captain W.E. Harris, No. 11/58, "Report on the Preparation of Gas Shell Bombardments. Canadian Corps – Attack on Vimy Ridge, 9 April 1917," n.d.

Harris prepared a useful guide to help gunners plan for engaging the enemy with chemical shells.[288] This guidance also stressed the importance of surprise, since the gas had its greatest effect on German gunners before they had the opportunity to don their respirators. The report also identified that enemy gunners did not need to be killed for the neutralization to be effective.[289] Dousing their battery positions in poison gas and forcing the artillerymen to don their respirators would hinder their ability to serve their guns. This report identified the shortcomings with *SS134 Instructions on the Use of Lethal and Lachrymatory Shell*, and the revised edition published in March 1918, included all the recommendations made by Harris.[290] It made its way to published doctrine withing months, which is a good thing. And it may very well have been practice before it appeared in writing.

After Vimy, the Canadian Corps almost exclusively used gas for counter-battery work. Artillery remained the preferred dispersal method of gas and, by 1918, counter-battery was the most important task for the guns. As the operational research conducted by the CBO revealed, the operational tempo during the Hundred Days campaign did not permit detailed intelligence gathering by multiple sensors that had been possible during static warfare. With limited intelligence on the disposition of the hostile batteries, gas, an area weapon, became increasingly useful for neutralizing enemy guns. Major-General Morrison directed that "[g]as concentrations will be freely employed – surprise effect will be striven for – the best results being obtained by a short and very intense burst of fire."[291] Harris had made all these recommendations in his operational report on the Vimy battle.

While not all officers in the Canadian Corps embraced gas, the artillery certainly did. During the Hundred Days campaign, the artillery arguably used too much gas. *SS134* advised against engaging areas with gas that friendly troops would occupy, and, generally, the infantry did not penetrate far enough into the enemy's depth to seize the hostile battery positions.[292] The September 1918 introduction of the British mustard gas shell, which was a more persistent agent than other gases, proved particularly useful for engaging static targets, like hostile batteries. The agent continued to harm soldiers even after they put their gas masks on. Due to the persistence of mustard gas, the GOC RA retained authority for its use.[293] Generally, the Canadian Corps does not seem to have been overly concerned about its infantry fighting through and consolidating in chemically contaminated areas. Before the assault on Bourlon Wood (27 September 1918), the artillery saturated the forest with 17,000 gas shells over fifteen days before the attack and another 7,600 after zero hour.[294]

While the CCGS continued to conduct some operational research throughout this period, the collection of data for the offensive use of chemical weapons proved difficult. With his limited staff, Harris could not conduct post-battle data collection in the same way that the staff-flush CBSO could do. Nor could his officers determine the effects of gas because its effects did not last. There were no gas craters to analyze. Other than captured German documents or prisoner interrogations, the chemical

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[288] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, April 1917, Appendix V, Captain W.E. Harris, "Instructions for Firing Gas Shells," 6 April 1917.
[289] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, "Notes on Artillery preparation and Support of the Attack on Vimy Ridge. April 9th.1917," Captain W.E. Harris, No. 11/58, "Report on the Preparation of Gas Shell Bombardments. Canadian Corps – Attack on Vimy Ridge, 9 April 1917," 2, n.d.
[290] General Staff, General Headquarters, *SS134 Instructions on the Use of Lethal and Lachrymatory Shell* (France: Army Printing and Stationery Services, March 1918).
[291] LAC, MG30-E81, Morrison Papers, Vol. 2, Artillery Corps, Orders and Instructions, September – December 1918, GOC RA Canadian Corps, O.907/2 O.2, "Canadian Corps Artillery Policy," 1, 3 October 1918.
[292] General Headquarters, *SS134 Instructions on the Use of Lethal and Lachrymatory Shell*, 11.
[293] LAC, MG30-E81, Morrison Papers, Vol. 2, Artillery Corps, Orders and Instructions, September – December 1918, GOC RA Canadian Corps, O.907/2 O.2, "Canadian Corps Artillery Policy," 1, 3 October 1918.
[294] Cook, *No Place to Run*, 204.

advisor had to rely on anecdotal evidence about how effective the German defensive fire was to determine how well the gas bombardments worked. Assessing protective measures and anti-gas training was a little easier, however, because Harris and his staff could always monitor Canadian gas casualties reported by the CAMC. A spike in the number of casualties could indicate poor gas discipline, ineffective protective equipment, a new German tactic, or a new agent. In any case, further data could be collected, analyzed, and mitigation measures implemented. On 3 December 1917, the CCGS disseminated a new directive to the divisions warning them that the Germans would soon likely use gas dispersed by trench mortar.[295] The directive warned that the Germans could form dense clouds of gas with minimal warning and stressed the importance of maintaining discipline and continual anti-gas training. On the night of 8-9 December, the Germans bombarded the 2nd Canadian Division with a mixture of gas and high explosive shells.[296] The DGO investigated of the bombardment and presented his findings in a detailed report similar to the report that the 2nd Canadian Divisional Artillery gas officer had submitted to Harris in September 1917.[297] The division sustained no gas causalities, and the "Gas-proof dugouts gave excellent protection."[298] The new procedures and techniques that Harris had recommended less than a week before had paid off. The CCGS again revisited its procedures after the Germans inflicted several gas casualties on 30 December. An investigation revealed that due to the cold weather the gas casualties had failed to remove their woollen caps before donning their respirators, which resulted in a poor seal.[299] Within one day, Harris circulated a letter throughout the Canadian Corps reinforcing the importance of properly conducting anti-gas drills.[300] This quick observation-hypothesis-action cycle was operational research at its best.

Like the CCGS, the staff of the CMGC also had difficulty quantifying the effects of a machine-gun barrage. Unlike shellfire, which left craters and damage to equipment, the effects of indirect machine-gun fire could not be easily determined or measured. One British machine-gun officer noted, "The general result must be regarded as probably considerable but certainly incalculable."[301] Furthermore, the CMGC rarely had enough forward observers to adjust fire and provide battle damage assessments. That situation did not improve. It did not help that the artillery, as an institution, did not believe in the efficacy of indirect machine-gun fire. McNaughton proved most critical:

> I was all for employing machine-guns to fire indirectly on the appropriate occasion but the trouble was, once you had this art of indirect fire, or at least once you thought you had it, the tendency was to use it when it wasn't apt. The machine-gun, you must never forget, is a weapon of opportunity. If it gets one burst in against a few Germans coming up in a file, or something of that sort, it's paid for itself. But you can fire thousands of rounds in indirect fire and the Germans wouldn't even know they'd been fired at because they're usually scattered over too wide an area and the bullets would merely prick the air. The expectation of a kill is low and, unlike a shell, the danger space is very short.[302]

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[295] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, December 1917, Appendix A, Captain W.E. Harris, Chemical Advisor, Canadian Corps, 9/142 "Circular regarding use of T.M. Gas shells similar to British projectors by the enemy," 3 December 1917.
[296] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, 9 December 1917.
[297] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, December 1917, Appendix B, Captain A.B. Campbell, D.G.O., 2nd Canadian Division, "Report on Gas shell bombardment area of 2nd Cdn. Divsn. on 8/9-12-17," 10 December 1917.
[298] Ibid.
[299] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, 31 December 1917.
[300] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, December 1917, Appendix K, Captain W.E. Harris, Chemical Advisor, Canadian Corps, No. 7/149 "Letter Regarding adjusting of S.B.R. while wearing woollel [*sic*] caps," 31 December 1917.
[301] R.M. Wright, "Machine-Gun Tactics and Organization," *The Army Quarterly* Vol. I (January 1921): 294.
[302] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 7, 9-10, 17 January 1963.

Even machine-gun soldiers questioned its effectiveness. Despite their use of motor transport to move to different sectors of the front, the machine gunners often had to carry their guns and ammunition forward on mules or their backs. While the engineers built light rail to keep the guns supplied with shells, the five million round fire plan fired by the CMGC at Vimy relied on soldiers moving the ammunition forward on foot. That was a strain.[303] Private Donald Fraser's comment on machine gun indirect fire is telling: "Tonight I shot away a couple thousand rounds of indirect fire. Indirect firing is not very satisfactory – you cannot see the target and, of course, do not know what damage, if any, is done. Besides, the belts have to be refilled and it is a blistery job forcing shells in with the palm of the hand without a protective covering."[304]

The evidence used to substantiate the effectiveness of machine-gun barrages is sparse. Quantitative assessments of the technique are limited to behind-the-lines studies like the one conducted on the wet beach sand at low tide. After-action studies invariably relied upon anecdotal or questionable evidence. Even the metric used to determine that indirect machine-gun fire prevented the resupply of German trench mortars at Vimy was questionable. Mortar bombs are not artillery shells. When a mortarman drops a bomb down the tube, there is no empty casing like there are for artillery pieces that would accumulate around the gun. Intelligence officers collected most information from prisoner interrogations. During Passchendaele, one report noted "Prisoners of the 76th Fus[ilier]. Reg[imen]t. state that the 111th Div[ision]. which sustained our attack on the 26th Oct. suffered very severely both from our artillery and M.G. barrages, the counter-attacks of the supporting batt[alio]ns being particularly severely handled."[305] Other reports cast doubt on the effectiveness of the machine-gun tactic. After Valenciennes, McNaughton asked the artillery intelligence officer to scrutinize the claims that the GOC CMGC had made about the effectiveness of the machine-gun barrage. "I told our intelligence officer to ask every prisoner of war whether, in marching up to counter-attack, he had come under machine-gun fire. We couldn't get a German prisoner from any of the counter-attacking battalions to say that he even knew he was being fired at."[306] Reports from Canadian infantrymen are similarly contradictory. To the infantry, fire support is fire support, and it would be impossible to distinguish between effects on the enemy from shellfire or a machine-gun barrage with thousands of guns simultaneously firing. The most that these studies concluded about indirect machine-gun fire was that it likely had some effect on the enemy, especially when it came to re-entering artillery-damaged areas to do repairs, but that the logistical requirements to sustain the technique made it inefficient compared to the artillery.

Like the staff of the CBO, the officers of the CMGC and CCGS conducted operational research. Armies had not used gas or machine-gun barrages on the battlefield before 1915. However, by 1918, the Canadian Corps had mastered both and incorporated these techniques into its fire plans. In the intervening years, gas officers needed to develop countermeasures to enable Canadian troops to survive on the chemical battlefield and produce doctrine on how gas could be used offensively by the corps (*innovation*, *trials*, and *experimentation*). Unlike the case of counter-battery, the experimentation was more ad hoc and relied upon statistical analysis of gas casualties to gauge the effectiveness of countermeasures. Anecdotal evidence provided data for the analysis of the effectiveness of chemical bombardment. Similarly, operational research on the use of machine guns firing in an indirect role could have benefited from more numerical analysis.

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[303] Papers of Private Richard William Mercer, "Randall Hansen Transcript," October 1970, courtesy of Dwight Mercer. I am grateful to Dwight Mercer for providing me with this reference.
[304] Reginald H. Roy, ed., *The Journal of Private Fraser, 1914-1918: Canadian Expeditionary Force* (Victoria: Sono Nis Press, 1985), 251.
[305] LAC, RG9-III-D-3, Vol. 4854, File number 142, War Dairy 3rd Canadian Division – General Staff, November 1917, Appendix 996, "3rd Canadian Division Summary of Intelligence From 12 noon 1st to 12 noon 2nd November 1917," 2.
[306] LAC, MG30-E133, McNaughton Papers, Vol. 358, "Flanders Fields Transcripts," Tape 9, 14, 15 February 1963.

Chapter 3 – The Legacy of the Canadian Corps and Operational Research

The staff officers and commanders of the CBO, CCGS, and CMGC all conducted operational research as we now understand it. The three staffs applied the methods of science to the complex problems of their First World War weapon systems and sought to improve both the effectiveness and efficiency of these systems. To do so, they developed hypotheses that they tested during trials and experiments. From these tests, the officers collected data, measured results, and compared outcomes. The purpose and findings of these tests could then be shared within the Canadian Corps and with other formations. Without the innovation, trialling, experimentation, and dissemination of findings by these staff officers, the Canadian Corps could never have become as proficient as it did at counter-battery fire, machine-gun barrages, or chemical warfare. Nevertheless, few historians other than Finan and Hurley have recognized the pioneering work of the Canadian Corps in this discipline. Why?

Historian Maurice Kirby argues that the scientific analysis conducted by officers like Andrew McNaughton, Raymond Brutinel, and Eric Harris "resembled operational research in one sense only, namely the close cooperation in developing new weapons systems between technically proficient … officers and civilian scientists and engineers. The remit of the latter was still confined to the material of war with little or no input into tactical or strategic analysis."[307] This argument is incorrect at both the tactical and strategic levels of war. The operational research conducted by the Canadian Corps analyzed the lethality of weapon systems on the battlefield. Not only did the output of the research make the BEF tactically superior to the German Army by 1918, the combined effects of counter-battery fire, gas, and machine-gun barrages enabled the Canadian Corps to kill Germans efficiently. Worn-out and ground-down through incessant attritional pounding, the Germans had no viable strategic option in November 1918 but to surrender. The consequences of their research extended beyond the battlefield. In his staff college lectures, Alan Brooke noted that the massive quantities of shells required for the counter-battery shoots required huge increases in the rate of production on the home front and increased capacity in the ammunition supply system.[308] Producing newly designed fuzes and shells or respirators slowed production and took time to retool factories. Operational research enabled the staffs to determine if the opportunity cost of implementing or manufacturing an innovation was worth that effort.

Kirby takes greater issue with the lasting impacts of the operational research done by officers like McNaughton, Brutinel, and Harris. He writes that their studies "did not result in the sustained and conscious use of scientific techniques in the planning and execution of military operations."[309] But this was not the case during the First World War. In no other period of history did armies have to adapt or change so quickly; nor has it ever been done as well. Of the three techniques, only counter-battery fire or the primitive concept of it existed before the war. By the Armistice, counter-battery fire, gas, and machine-gun barrages comprised the essential elements of the Canadian Corps fires to shape the battlefield. Furthermore, the Canadian Corps masterfully used all three techniques. Still, Kirby does raise an important question. What was the legacy of the operational research conducted by the Canadian Corps? This chapter examines the lasting impacts of the operational research conducted by the CBO, CMGC, and CCGS. It also identifies the links between these studies and the work of No. 2 ORS during the Northwest Europe campaign of the Second World War.

The counter-battery system perfected by McNaughton lasted through the Second World War. In January 1919, Lieutenant-Colonel H.D.G. Crerar prepared a report on the organization and procedures of

[307] Kirby, *Operational Research in War and Peace*, 32.
[308] LHCMA, Alanbrooke Papers, 3/10, "Evolution of Artillery in the Great War 1914-1918," 366.
[309] Kirby, *Operational Research in War and Peace*, 42.

the CBO in the Canadian Corps for submission to GHQ.[310] The report was well-received, and McNaughton wrote his protégé. "Got an acknowledgement from G.H.Q. on the C.B. report.… I think you have let things off very well indeed. And the information should be of great help in the study of the Science prior to a future war."[311] The Royal Artillery's counter-battery techniques during the Second World War had changed little from the Hundred Days. Air observers provided most of the intelligence during mobile phases, and sound-rangers, flash-spotters, and radars proved useful, but only when the front remained static for an extended period.[312] McNaughton and the staff of the CBO had made this observation in their report after Vimy. The postwar dissemination of the counter-battery methods of the Canadian Corps even extended beyond the British Empire. The United States III Corps asked Crerar for a copy of the January 1919 report that he had submitted to GHQ. The letter from the American artilleryman stated: "[F]rom all accounts there was no place in the Allied armies where counter battery work was so effective. I hope our service will be able to draw further lessons from this pamphlet and to further perfect our own organization."[313]

Both Brooke and McNaughton gave staff college lectures at Camberley on counter-battery methods during the interwar years (another form of *dissemination*). Their teaching ensured that the lessons learned during the Great War did not need to be relearnt by the generation of artillery officers that would fight the next world war. Historian Jonathon Bailey notes, "The significance of the new thinking of 1917-1918 lay not so much in how it determined the outcome of the First World War, but in how it formed the seed-bed for the new techniques of fire and manoeuvre developed in the 1920s and 1930s and practised in the Second World War."[314] Brooke emphasized the scientific methods required for counter-battery work to his students.[315] He stressed that neutralizing the enemy's guns was a priority for the artillery. "The necessity for engaging the hostile artillery during an attack stands out very clearly as one of the lessons of the war.… We were repeatedly shown that failure to obtain mastery of the hostile artillery jeopardised the success of the operations as a whole."[316] McNaughton amplified Brooke's arguments in two articles published in the *Canadian Defence Quarterly* journal – "Counter Battery Work" and "The Development of Artillery in the Great War."[317] Despite their later differences, Brooke and McNaughton left Second World War gunners with a far more extensive body of knowledge on counter-battery work than the meagre few paragraphs of *FAT* that they may or may not have read in 1914.

Despite the operational research studies done by the CMGC to develop the machine-gun barrage and improve its effectiveness, machine gunners did not conduct indirect fire during the Second World War. Brutinel had returned to his residence in southern France and resumed his banking career after the

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[310] LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 7, File 10, CBO, C.B. 18/4-4, "Organization and Procedure of the Counter-Battery Staff Office," 25 January 1919. Crerar had previously established himself as an authority on counter-mortar operations. His experimentation with trench mortars of McNaughton and the senior artillery officers in First Army. Paul Douglas Dickson, *A Thoroughly Canadian General: A Biography of General H.D.G. Crerar* (Toronto, Buffalo, and London: University of Toronto Press, 2007), 58-60.

[311] LAC, MG30-E157, General Henry Duncan Graham Crerar Fonds (Crerar Papers), Vol. 18, Field Messages and Correspondence, Letter from Brigadier-General A.G.L. McNaughton to Lieutenant-Colonel H.G.D. Crerar, 2, 3 March 1919.

[312] G.W.L. Nicholson, *The Gunners of Canada: The History of the Royal Regiment of Canadian Artillery, Volume II, 1919-1967* (Toronto and Montreal: McClelland and Stewart Limited, 1972), 163, 312, 375, 401.

[313] LAC, MG30-E157, Crerar Papers, Vol. 18, Field Messages and Correspondence, Letter from Headquarters Third Army Corps, American Expeditionary Forces Germany, to Lieutenant-Colonel H.D.G. Crerar, 27 January 1919.

[314] Bailey, "British Artillery in the Great War," 38-39.

[315] On Brooke's time as Directing Staff at Camberley, see David Fraser, *Alanbrooke* (New York: Atheneum, 1982), 86-92.

[316] LHCMA, Alanbrooke Papers, 3/10, "Evolution of Artillery in the Great War 1914-1918," 478.

[317] McNaughton, "Counter-Battery Work;" and "The Development of Artillery in the Great War."

war.[318] Without its forceful patron, the independence of the CMGC became increasingly doubtful, especially considering the British began disbanding their Machine Gun Corps in 1919.[319] In 1936, the Canadian Militia disbanded the CMGC and reassigned some infantry battalions as machine-gun battalions.[320] Without practice, the ability to conduct indirect fire waned. Brutinel regretted this deterioration of the skill set and noted: "It is evident that the doctrine of the Canadian Machine Gun Corps will be also forgotten until the next Blood letting when it may have to be learned again, perhaps at a great cost."[321] During the Second World War, First Canadian Army retained one machine-gun battalion per infantry division; however, these machine gunners no longer fired their weapons as part of a barrage. Nor did they attempt to relearn how to fire machine-gun barrages. McNaughton may have been responsible for this loss of capability since he had never really believed in the effectiveness of the tactic.[322] He served as Chief of the General Staff from 1929 until 1935 and as commander of First Canadian Army until December 1943, so he had the authority to stifle all attempts to revive the technique. The infantry used machine guns only for direct fire during the Second World War. Except for infantry mortar platoons, only the artillery conducted indirect fire.

The CCGS had an even shorter existence than the CMGC. Harris issued his final order telling soldiers to carry their respirators on their person on 20 December 1918, and the gas services were disbanded one month later.[323] Despite the disbandment of the Directorate of Gas Services on 22 May 1919, the British continued to study chemical warfare, and Winston Churchill, then the Secretary of State for the Colonies, even proposed using it against Afghan tribesmen on the Northwest Frontier.[324] While the British did not use gas in their small wars, a July 1919 report stressed the importance of peacetime preparation. "Ample and generous provision must be made for the continuous study of chemical warfare both as regards offence and defence during peace, in order to ensure the safety of the fighting forces of the Empire."[325] Several officers in the Canadian Corps had recommended forming gas companies, like the British Special Brigade. However, the Ministry of Overseas Military Forces of Canada never acted on the recommendation, so Canada had no offensive gas capability other than the artillery.[326] Even the defensive expertise of the CCGS lapsed. Despite concerns over the stockpiles of chemical weapons maintained by some countries, the Canadian Militia had no money or staff during the interwar period for operational research in chemical warfare.[327] Fortunately, combatants did not use chemical weapons against each other during the Second World War. Nevertheless, Canadian soldiers continued to undergo anti-gas training, and the Canadian government established the Chemical Warfare School in Suffield, Alberta, to continue research.[328] The technology and procedures for defence against chemical warfare had advanced little since the Great War.

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[318] Pulsifer, "Canada's First Armoured Unit," 56.
[319] Bidwell and Graham, *Fire-Power*, 193.
[320] Grafton, *The Canadian "Emma Gees,"* 216-218.
[321] CWM, George Metcalf Archival Collection, 20020045-1525, "The Raymond Brutinel Tapes," Tape 17, 1, 18 October 1962.
[322] Schreiber also arrives at this conclusion. Schreiber, *Shock Army of the British Empire*, 82.
[323] LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, 20 December 1918.
[324] Richter, *Chemical Soldiers*, 214; and Marion Girard, *A Strange and Formidable Weapon: British Responses to World War I Poison Gas* (Lincoln and London: University of Nebraska Press, 2008), 182.
[325] TNA, WO 33/3114, War Office, "Report of the Committee on Chemical Warfare Organization," 1, 7 July 1919.
[326] Cook, *No Place to Run*, 143.
[327] C.P. Stacey, *Arms, Men and Governments: The War Policies of Canada, 1939-1945* (Ottawa: Queen's Printer, 1970), 3.
[328] C.P. Stacey, *Official History of the Canadian Army in the Second World War, Volume I, Six Years of War: The Army in Canada, Britain and the Pacific* (Ottawa: Queen's Printer and Controller of Stationery, 1955), 136, 240, 246.

Without the pressing necessity of war, the blistering pace that staffs had conducted operational research slowed. Still, the British Army did not completely disregard the lessons that it had learnt during the First World War. A 1932 committee chaired by Lieutenant-General Sir Walter Kirke highlighted the necessity of keeping "abreast of modern scientific developments…. There is always the danger that a new war may find us surprised again by scientific weapons."[329] The Kirke committee report also stressed the importance of close cooperation with civilian scientific experts.[330] Still, operational research historians have criticized the supposed dearth of development during the interwar years. "The designers led, the tactics lagged, and effective countermeasures were virtually non-existant."[331] Operational research requires the desired end states and that the efficiency and effectiveness of the system can be analyzed to achieve its purpose better. During the interwar period, the Canadian Militia and even the British Army struggled to maintain the doctrine, staff proficiency, and technical capabilities to fight a first-class enemy.[332] Efficient and effective weapon systems based on sound scientific principles were the legacy of operational research conducted by the Canadian Corps and the BEF during the Great War.

During the Second World War, the British Army did not regain a comparable level of tactical proficiency until Lieutenant-General Bernard Montgomery's Eighth Army defeated the Germans in North Africa in late 1942.[333] As commander of the Eighth Army and later 21st Army Group, Montgomery used fires to support his manoeuvre forces and fight the deep battle in ways that were unimaginable for Haig and Currie.[334] Historian David French argues, "The key to the British army's success from Alam Halfa onwards was that they had discovered how to employ the weapons they possessed in such a way as to exploit their opponent's weaknesses."[335] Their "discovery" did not happen by chance. It was the result of systematic studies of the army's weapons and operational methods. In May 1941, Chief of the Imperial General Staff, General Sir John Dill appointed Sir Charles Darwin to be the scientific advisor to the Army Council.[336] Both had connections with the Canadian Corps CBO. Dill had frequently visited McNaughton there, and the CBO targeted hostile batteries that had been located by Darwin's sound-rangers. Both Dill and Darwin undoubtedly understood the importance of operational research to the art of war.

Dedicated operational research staffs conducted dozens of studies during the 1939-1945 War. Unlike the staffs of the Canadian Corps CBO, CMGC, and CCGS – whose primary task was to manage operations – the British military had over 1,000 scientists working, unencumbered with anything but research responsibilities, in its operational research units, and the army specifically had 200 researchers.[337] Established in July 1943, No. 2 ORS formed part of the headquarters of 21st Army Group – the British Army's Second World War equivalent of GHQ. Monty had a much tighter grip on the planning and conduct of operations than Haig and GHQ ever did. Commanded by Brigadier Basil Schonland, a South African physicist, the scientists of No. 2 ORS strove towards the "solving of 'conundrums'" for the army group.[338] No. 2 ORS comprised ten officers, one sergeant, one corporal, and

[329] TNA, WO 33/1297, War Office, "Report of the Committee on the Lessons of the Great War," 8, 13 October 1932.
[330] Ibid.
[331] McCloskey, "The Beginnings of Operations Research,"144.
[332] John A. English, *The Canadian Army and the Normandy Campaign* (Mechanicsburg: Stackpole Books, 1991), 20-38.
[333] David French, *Raising Churchill's Army: The British Army and the War against Germany, 1919-1945* (Oxford: Oxford University Press, 2000), 262.
[334] Ibid, 255-258.
[335] Ibid, 273.
[336] Copp, "Scientists and the Art of War," 65.
[337] McCloskey, "British Operational Research in World War II," 462-465.
[338] B.F.J. Schonland, "Working with Montgomery: On Being a Scientific Advisor to a Commander-in-Chief (21 Army group 1944-1945)," *Canadian Military History* Vol. 15, no. 3 and 4 (Summer – Autumn 2006): 133.

eleven other ranks.[339] Assigning the ORS to the army group headquarters gave the scientists access to the key commanders and staff, much like McNaughton had enjoyed as CBSO. This type of access was necessary for implementing recommendations that improved the effectiveness and efficiency of operations. The style of battlefield command had evolved since the First World War. Radios enabled Montgomery to command much further forward than was previously possible. And he did. Consequently, Schonland mostly dealt with Montgomery's Chief of Staff, Major-General Sir Francis de Guingand. The senior leadership of the Canadian Corps had supported the operational research conducted by the CBO, CMGC, and CCGS. Their patronage was in large part a precondition for the success of operational research in the corps. Schonland had a similarly cooperative relationship with de Guingand. Schonland noted the "friendship, support, interest and insight" that de Guingand gave him.[340] De Guingand empowered the ORS and ensured that the operations and artillery staff officers actioned the recommendations in the operational research reports.

Incorporating operational researchers into operational headquarters operations was necessary, as the experience of the Canadian Corps during the Great War had demonstrated. Staff officers had to action the recommendations from trials and experiments and implement them during subsequent operations. The process then began again. It was a cycle, without which it would have been difficult or impossible to improve efficiency or effectiveness. Lord Blackett, a physicist and authority on operational research, wrote:

> The object of having scientists in close touch with operations is to enable operational staffs to obtain scientific advice on those matters which are not handled by the service technical establishments. Operational staffs provide the scientists with the operational outlook and data. The scientists apply scientific methods of analysis to these data, and are thus able to give useful advice. The main field of their activity is clearly the analysis of actual operations, using as data the material to be found in an operations room, e.g. all signals, track, charts, combat reports, meteorological information, etc. [I]t will be noted that these data are not, and on secrecy grounds cannot, be made available to the technical establishments. Thus such scientific analysis, if done at all, must be done in or near operations rooms. The work of an Operational Research Section should be carried out at Command, Group, Station or Squadron as circumstances dictate.[341]

Montgomery and other officers may not have liked having operational researchers around the battlefield. However, they understood the necessity of their work to leverage the strengths of British weapon systems and use them to target the enemy's weaknesses.

There are many continuities between the operational research conducted by the Canadian Corps during the First World War and the 21st Army Group during the Second World War. No. 2 ORS produced forty-three reports and memorandums during the 336-day long Northwest Europe campaign. The British and Commonwealth armies relied on massed fires to attrite the Germans before attacking with overwhelming force and inflicting "colossal cracks" on the enemy.[342] Monty's operational technique had the double effect of reducing infantry casualties and preserving the morale of his forces. Consequently, most of the studies conducted by No. 2 ORS focused on improving the effectiveness and efficiency of joint fires. The scientists proposed the usefulness of the GL Mark III radar for counter-mortar work, just

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[339] Copp, ed., *Montgomery's Scientists*, 19, 66.
[340] Schonland, "Working with Montgomery," 136.
[341] P.M.S. Blackett, "Scientists at the Operational Level" (1941), collected in Studies of War: Nuclear and Conventional (New York: Hill and Wang, 1962), 171.
[342] Stephen Ashley Hart, *Colossal Cracks: Montgomery's 21st Army Group in Northwest Europe, 1944-45* (Mechanicsburg: Stackpole Books, 2000), 2, 84-90.

like McNaughton had incorporated sound-rangers and flash-spotters into the Canadian Corps counter-battery system at Vimy.[343] Experiments conducted on the accuracy of predicted fire after Operations SWITCHBACK (9 October – 2 November 1944) and VERITABLE (8 February – 11 March 1945) mirrored studies that McNaughton and the CBO had conducted in June 1918 and yielded similar results.[344] The reports prepared on the effectiveness of counter-battery fire during the assault on Boulogne (17-22 September 1944) and VERITABLE mirrored the reports prepared by the CBO after Vimy and Passchendaele.[345] No. 2 ORS also disproved claims about the effectiveness of close air support aircraft against armoured vehicles during the closing of the Falaise Gap (12-21 August 1944). Their finding that Typhoon fighter-bombers primarily had a moral effect on German armoured crewman, despite the pilots' outlandish claims, echoes the findings of CMGC studies into the effectiveness of machine-gun barrages.[346] The findings of the report surprised de Guingand, but he was better off knowing that rockets fired from Typhoons rarely hit their targets and that aircraft had a mostly morale effect on the enemy.[347] In all reports, the methodology used by No. 2 ORS of testing hypothesis against collected data, analyzing results, and disseminating findings to make operations more effective and efficient mirrored the practices of the CBO, CMGC, and CCGS during the First World War.

McNaughton remained involved with operational research during the Second World War. As the commander of First Canadian Army, McNaughton gave considerable support to the work of the scientists – arguably at the expense of leading and training his army – and enlisted Omond Solandt, then Deputy Superintendent (second-in-command) of the Army Operational Research Group into the Canadian Army.[348] McNaughton set the conditions for the success of the operational research group being formed in Ottawa to support the Canadian Army. He noted that the group needed a broad mandate, access to key commanders and staff, and unencumbered with routine administration so that it could focus on its scientific work.[349] These were exactly the conditions that Radcliffe set for McNaughton when he was appointed CBSO in January 1917. Curiously, despite McNaughton's nationalist tendencies, he did not support proposals to form an ORS within First Canadian Army.[350] He preferred to keep the operational research organization as implemented by the War Office. This facilitated standardization and dissemination of findings from operational research studies. In this one instance, McNaughton prioritized efficiency and effectiveness over nationalist concerns and his vanity.

There are direct links between the operational research conducted by the Canadian Corps during the First World War and the work of No. 2 ORS during the Northwest Europe campaign, and the two organizations are connected. They both had the same purpose – make their weapon systems more effective and efficient. Many of the people involved with the operational research conducted by the Canadian Corps had a role in the formation of operational research units during the Second World War, including McNaughton, Darwin, and Dill. During the interwar period, Brooke, McNaughton, and others

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[343] Copp, ed., "Report No. 11 The Location of Enemy Mortars," in *Montgomery's Scientists*, 431-440.
[344] Copp, ed., "Report No. 24 Accuracy of Predicted Shooting," in *Montgomery's Scientists*, 311-323; and Copp, ed., "Report No. 31 The Accuracy of Predicted Fire: Operation VERITABLE," in *Montgomery's Scientists*, 295-310.
[345] Copp, ed., "Part of Report No. 16 The Assault on Boulogne," in *Montgomery's Scientists*, 333-336; and Copp, ed., "Report No. 29 Effect of Counter-Battery Fire in Operation VERITABLE," in *Montgomery's Scientists*, 337-348.
[346] Copp, ed., "Report No. 15 Enemy Casualties in Vehicles and Equipment during the Retreat from Normandy to the Seine," in *Montgomery's Scientists*, 181-205.
[347] Francis de Guingand, *Operation Victory* (London: Hodder and Stoughton, 1947), 327.
[348] Ridler, "Leadership and Science at War," 179.
[349] LAC, MG30-E133, McNaughton Papers, Series III, Vol. 153, P.A. 3-12, Joint Report on Army Research in Canada, Annex VI, "Minutes of Meeting Held at Headquarters First Canadian Army, 1700hrs, 16 August 1943," 19 August 1943.
[350] LAC, MG30-E133, McNaughton Papers, Series III, Vol. 153, P.A. 5-2, Letter from Lieutenant-General A.G.L. McNaughton to Dr. O.M. Solandt, 19 May 1942.

attempted to impart the lessons learned on the Western Front to the next generation of military officers. That they only partially succeeded owes more to budgetary restrictions and the general lack of purpose for the armed forces than negligence on their part. The methodology of Schonland and his scientists mirrored that of the staff of the CBO, CMGC, and CCGS. These researchers innovated, trialled, experimented, and disseminated their findings – the indicators of operational research. Even the "conundrums" tested by No. 2 ORS re-examined many of the same hypotheses studied by McNaughton and the staff of the CBO. No. 2 ORS did not do any operational research on the indirect machine-gun barrages or chemical warfare because the British and Commonwealth armies did not use these methods during the Second World War. Indeed, the differences between the operational researchers in the Canadian Corps and No. 2 ORS were those of organization and nomenclature. No. 2 ORS existed in the army group headquarters to conduct operational research. That was the only task for its staff. This staff was larger than the combined staffs of the CBO, GOC CMGC, and the corps chemical advisor, all of whom had to deal with operations primarily. Also, the specialized staffs of the Canadian Corps did not have a specific term that described their methodology. No. 2 ORS did – operational research.

Conclusion

Six main points are evident from this study of the scientific work conducted by the staff officers of the Canadian Corps during the First World War. First, these specialized staffs conducted operational research as we now understand it. Second, the Canadian Corps and the BEF were learning organizations that gave these officers the support they needed to conduct their research. Third, the findings of their operational research reports were widely disseminated across the BEF, the French Army, the U.S. Army, and eventually codified into the British Army's doctrine. Fourth, the effectiveness of a weapon system had to be measured by more than the physical effects caused by the weapon. The entire apparatus that supported the system had to be analyzed. For instance, the limitations of predicted fire needed to be understood before a counter-battery plan predicated on predicted fire could be executed. Fifth, while the operational research methodology strives for quantitative data, staffs relied upon anecdotal evidence to gauge the moral effects of various weapons. The ephemeral nature of gas clouds and machine-gun barrages meant that the operational research conducted by the staffs of the CMGC and CCGS relied heavily upon qualitative evidence. Last, operational research can be helpful to commanders at all levels of war for answering technical questions. Particularly the arms and services responsible for effects on the battlefield, such as the artillery, air force, and psychological operations, could benefit from a scientific analysis of their work.

Neither Andrew McNaughton and the gunners of the CBO, nor Eric Harris and his gas officers, nor Raymond Brutinel and his machine gunners ever used the term "operational research" to describe their scientific studies. However, they were undoubtedly its practitioners through their innovating, trialling, experimentation, and dissemination of knowledge – the four pillars of the discipline. The staff of the CMGC, for instance, incorporated the teachings of British Army machine-gun experts and conducted their own primitive indirect fire tests (*innovation* and *trials*). They integrated their weapon into the fire plans that supported corps operations in 1917 and 1918 and fired barrages that prevented German defenders from withdrawing or reinforcing and they made resupply and repair of defensive positions and obstacles perilous (*experimentation*). And they shared best practices with other formations in the BEF (*dissemination*). Artillerymen and gas officers also applied science to their respective weapon systems and, in doing so, made them as efficient and effective as possible. Through their studies, the Canadian Corps protected its soldiers from the worst effects of chemical weapons, and used gas, machine-gun barrages, and counter-battery fire to attrite the German Army and strike their most important systems. The application of operational research to these three systems resulted in the effective fires that supported the "shock army" of the BEF during the Hundred Days campaign. As McNaughton noted:

> It was largely because the British General Staff read these lessons correctly and had the courage of their convictions to effect the necessary reorganization that later we were able to beat the Germans, despite the fact that in the technical matters of guns and ammunition they still maintained their lead.[351]

As other historians have already argued, the BEF underwent an incredible learning process during the war. By 1918, the BEF had mastered tactics and techniques that had not even existed before the war. Prewar British doctrine barely mentioned counter-battery fire, but by 1918, counter-battery operations were the most critical task that the artillery performed as part of the all-arms battle. *FAT* did not tell gunners how to fight the artillery battle, but it did stress that the primary aim of the artillery was to support the infantry. That drove much innovation, and the principle remains unchanged to the present day. Attacks launched by the BEF in 1915 without silencing the German guns had almost always resulted in failure and high casualties. Artillerymen knew they needed to suppress the German guns to enable the infantry to assault across No Man's Land, seize the enemy's trenches and consolidate. However, primitive

[351] McNaughton, "The Development of Artillery in the Great War," 163.

technology and gunnery techniques, lack of intelligence, and decentralized control of artillery hampered early attempts to conduct counter-battery fire. The end of the Somme offensive marked a key moment for the development of the counter-battery capability. The formation of the CBO – a key lesson from the Somme – set the conditions for the British artillery to win the artillery firefight. And the staff of the CBO acted as the ORS. Operational research provided a link between the general principles contained in the prewar doctrine and the "how-to" manuals published by the BEF on the Western Front. The BEF compiled the findings of these operational reports prepared by these staffs and published them as *SS* pamphlets. The revised edition of *SS134 Instructions on the Use of Lethal and Lachrymatory Shell*, for instance, incorporated several recommendations made by Harris in the report that he had submitted to First Army on chemical operations in support of the assault on Vimy Ridge. This learning process did not stop. New theories would be proposed, trialled, experimented, reported on – and then the process began again.

This learning process extended beyond the ranks of the Canadian Corps and the BEF. Initially, the Canadian Corps adopted some of its best practices from the French Army. It then experimented with these techniques, made modifications, and then shared its best practices with the French. Despite his postwar claims, McNaughton and the staff of the CBO exploited this mechanism on several occasions. As the Canadian Corps acquired a reputation for tactical proficiency, other British, French, and American formations sought out the best practices of the corps. There is no evidence to support the argument that the Canadian Corps was more receptive to innovations from civilian scientists or officers with scientific knowledge than other BEF corps. Neither can the CEF take credit for the formation, structure, and operating procedures of the CBO. Much of the system that McNaughton implemented came directly from *SS139/3*. Brutinel shared his machine-gun barrage technique with Fayolle and the machine gunners of the *Groupe d'armées du Centre*. The American III Corps asked Crerar for a copy of the report he had prepared for GHQ on the organization and procedures of the Canadian Corps CBO so that they could structure their counter-battery capability based on the Canadian example. Operational research was more than just studying a problem and finding solutions. To be meaningful, these solutions had to be shared, and these examples of dissemination demonstrate that the staffs of the Canadian Corps understood the importance of their work.

Operational research enabled the Canadian Corps to manage and understand the effects of its weapon systems. While the development of the flash-spotting and sound-ranging techniques were feats, they still had to be integrated into a targeting system to attack the hostile batteries identified by these novel methods. The report prepared by McNaughton after Vimy highlighted the staffing shortfalls in the CBO, which made it difficult to analyze all the intelligence collected by the sensors. It is unlikely that the Canadian Corps CBO could have maintained the battle rhythm of the Hundred Days campaign without these additional staff. These scientific studies also provided accurate battle damage assessments. In the case of the artillery, predicted fire was not nearly as accurate as many historians have claimed. Sound-rangers and flash-spotters were only useful on static fronts. Destructive shoots required more intelligence, ammunition, and time to achieve than were available during periods of mobile warfare.

Both the CMGC and CCGS benefited from the innovative work done by British officers and formations. Brutinel and the Canadian machine gunners could not have perfected the machine-gun barrage without the pioneering work done by Lindsay. Furthermore, two British divisions at Loos had already demonstrated what a machine-gun barrage could achieve before Canadian Corps machine gunners fired a single barrage in support of a major operation. Brutinel's forceful personality ensured that the staff of the CMGC had the proper organization and support of the senior officers of the Canadian Corps. His personality also brought him into conflict with several British officers and obscured the origins of indirect machine-gun fire. Harris also benefited from the work done by others. Almost immediately following the German gas attack during the Second Battle of Ypres, British and Canadian officers had innovative solutions to protect soldiers from the effects of gas. Initially, these measures were primitive, but

eventually, the British Gas Services developed protective equipment and procedures that it implemented across the BEF. Necessity drove the development of countermeasures.

Harris had little involvement in the development of offensive gas methods. Before the widespread introduction of gas shells in the BEF in 1917, the British Special Brigade commanded by C.H. Foulkes conducted numerous gas attacks on the Germans. Canada had mixed experiences with canister-dispersed gas. After the failure of the March 1917 gas raid at Vimy, the Canadian Corps never used canister-dispersed gas to support the infantry. The gas shell proved particularly useful for counter-battery work, and Harris worked closely with the Canadian Corps artillery to improve techniques and methods. By 1918, the area coverage artillery-delivered gas helped make up for time-limited intelligence-gathering and target acquisition. And Harris did much operational research on the effectiveness of gas countermeasures. The trials conducted by the CCGS gave soldiers confidence that the equipment would protect them from gas. He also worked closely with the CAMC to minimize the effects of German chemicals on the Canadian Corps. He succeeded.

When it came to gas and machine guns, the added responsibility of overseeing training sometimes helped and sometimes hindered operational research. For Brutinel and the CMGC, training allowed the staff to collect quantitative data on the accuracy and precision of indirect machine-gun fire. Training also standardized the complex methods required for indirect fire. For the CCGS and Harris, on the other hand, training proved a distraction from operational research. Although Harris standardized gas training in the formations and schools of the Canadian Corps, his authority did not extend to chemical warfare training in the United Kingdom and efforts to try and sort it out proved a wheel-spinning exercise for someone who had responsibility but no real authority. For the duration of the war, reinforcement drafts left England for the Western Front ill-prepared for survival in a chemical environment. Harris had to spend an excessive amount of time trying to sort out this unsatisfactory situation, all to the detriment of operational research.

The operational research conducted by the staff of the CCGS nor the CMGC suffered from limited numbers of personnel and the difficulty of quantifying the effects of the weapons systems. Neither the machine gunners nor the gas officers had a staff like the CBO. The primary concern for both staffs remained operations, so operational research had to occur during lulls in operations. Still, both the staff of the CCGS and the CMGC had a mixture of scientific and administrative backgrounds. These men knew how to analyze systems and present their findings coherently, two skills necessary for good operational research. The effects of gas and machine-gun barrages were much harder to quantify than counter-battery work. Both the operational research conducted by machine gunners and gas officers necessarily suffered from a lack of quantitative data. While McNaughton could determine the effectiveness of a counter-battery shoot by counting the number of wrecked pieces and destroyed gun pits. The CMGC and CCGS attributed the success of their barrages and bombardments to moral effects. While not ideal, operational research could nevertheless use anecdotal evidence, but the report had to address the limitations of this type of evidence. Reports on the effectiveness of machine-gun barrages are instructive. For every German prisoner who reported that the barrage prevented his unit from withdrawing or being reinforced, another prisoner stated that he did not even know that indirect machine-gun fire had engaged his unit. Even so, when it came to machine-gun fire or even the use of gas, the operational research indicators – innovation, trials, experimentation, and dissemination of findings – were there, however imperfectly they may have been done.

The history of operational research needs revision and further inquiry. This study finds that three specialized staffs in the Canadian Corps headquarters conducted operational research with varying degrees of rigour during the First World War. Several of the studies conducted by these staff officers were mirrored by investigations carried out by No. 2 ORS during the Second World War. Several key personalities associated with operational research in the Canadian Corps during the Great War, including

Charles Darwin, John Dill, and McNaughton, had a direct role in the formation of army operational research units during the 1939-1945 War. These units conducted their studies with the same methodology used by their predecessors in the First World War. The Canadian Corps comprised but four divisions in a sixty-plus division BEF that also included formations from Australia, India, New Zealand, South Africa, and the United Kingdom. The British Empire also deployed sizeable forces to operational theatres in Africa, the Balkans, and the Middle East during the war. These theatres had several of the same challenges, but they also had their unique difficulties. More scholarly attention is warranted to determine how uniformly the BEF and other expeditionary forces conducted operational research to solve these problems and support the decision making of commanders with science. To do so, historians must move beyond semantics and recognize earlier forms of operational research that predate its supposed origins in the mid-1930s. Instead of looking for the term operational research, scholars should look for operational research itself.

Appendices

Appendix A

SECRET

Counter Battery Office.
C.B.636/20.

G. O. C., R.A.,
Canadian Corps.

The attached appendices are an analysis of the results of the Shoots by the Canadian Corps Artillery with Aeroplane Observation, between December 26th.1917 and May 4th.1918 The analysis is for the purpose of obtaining:-,

Object. 1. The comparative accuracy of the various guns and howitzers when fire is directed from the Map [predicted fire].

2. The average number of Ranging Rounds for each Calibre, the time taken by the Aeroplane in calling up and commencing Ranging, and the time from the commencement of fire till the completion of Ranging.

3. During Fire for Effect, the changes in Elevation and Line necessary to keep the M.P.I. [mean point of impact] on the Target. The number of rounds and the time taken in the process of Re-ranging.

GENERAL

CONSIDERATIONS. The Maps of the district are reasonably accurate, the co-ordinates of the Target determined with precision, and the Batteries have had the services of a Typographer to resect the positions of their Guns.

The majority of the Shoots were observed by a Squadron thoroughly familiar with the area, so that confidence may be felt in the correct selection of the "Ranging Points".

The Front has been stationery for a considerable number of months, so that the Battery positions are more or less permanent, with good platforms and unusually good facilities for the supply and storage of Ammunition

/Good observing....

Good Observing localities overlooking the main areas in which shoots are carried out, permit of Calibration by the Battery Officers themselves on definite points in the vicinity of their Targets.

Complete Telephone communication facilitates the rapid circulation of "Meteor" reports.

In short, the conditions affecting the accuracy of "Map" shooting are probably as favourable in this Section as anywhere on the Front.

Results. Appendix "A" gives the average performance of each Battery which has carried out shoots with Aeroplane Observation during the period.

The figures under "Average Corrections to Elevation and Deflection" are the average corrections that the Battery Commander has had to give in order to bring the M.P.I. on to the Target. In other words, the average amount that the M.P.I. would have been off the Target if fire had been directed from the Map.

Appendix "B" is a synopsis by Calibres of the results given in Appendix "A". It represents the average performance of each type of Gun or Howitzer.

It would appear that the average time spent by the Airman in calling up is about 15 minutes. The average time taken to Range is about one hour. The average "Ranging Rounds Observed" [is] about 7 per Gun.

With the 4.5"How. and the 6" Gun only about 50% of the Ranging Rounds are spotted by the Observer. With the 8" and 6" Hows.,and 60.Pdrs.,about 70% and with the 8".Mk.VII and the 9.2" Hows. about 90% are observed.

/Appendix "C" shows....

Appendix "C" shows the results of Re-ranging in those shoots in which it was necessary and possible to carry it out.

The figures under "Corrections to Elevation and Line" represent the average amount that the M.P.I. had shifted off the Target during Fire for Effect. The magnitude of this shift of M.P.I. is so considerable that in a very large number of cases the Target is practically outside the 100% Zone of the Gun.

This points to the necessity of continuing observation during Fire for Effect.

The average number of R.R.O. [ranging rounds observed] per Gun in Re-ranging is about 5 and the average time taken about 30 minutes.

Fire for Effect

Appendix "D" gives :-.

1. The Probable Error of a round from the M.P.I.

2. The probable Error of the M.P.I. from the Target if fire is directed from the Map.

3. The probable Error of a round from the Target when fire is directed from the Map.

4. The expectation of hits on various types of Targets with Map and Observed Shooting respectively and a comparison of their relative efficiency.

Discission of Results.

It will be seen that the best performance is that of the 60.Pdr; the worst, that of the 6" How. Of the Heavy Hows, the 8" is more accurate for Range but less accurate for line, than the 9.2" How.

As will be noticed, the Errors introduced in Map shooting are very large, and the expectation of hitting a Target is consequently reduced to a low figure.

/Comparison of the....

Comparison of the results on Targets "A" and "B" shows that for Map Shooting there is very little advantage in "Enfilade" over "Frontal" fire.

If the results of the individual Batteries shown in Table "A" are compared with the average performance of their particular Calibre shown in Table "B" it will be evident that the efficiency of certain Batteries is far below that possible under existing conditions.

This points to a lack of training and care in calculating and applying Initial Corrections, to Storage of Charges under unsatisfactory conditions, to lack of sorting charges by Lots and of Shell by Type and Driving Band, and to incorrect adjustment of Sights.

A lot of improvement could be effected in the Shooting if more attention were paid by the Department of Munitions to the standardization of Type and uniformity of manufacture of Shells, Driving Bands and Propellants, and the Ammunition Authorities at the Base and on the L. of C. [line of communication] could be of considerable assistance if a comprehensive scheme of sorting and distribution by "whole Lots" were put into force.

With regard to the marked efficiency of the 60.Pdr. as compared with the other Calibres – this is mainly due to the short time of Flight.

For instance, at 10,000 yards the comparison of the 60.Pdr. with the 6"How. (charge 5) in a wind of 100 f.s at 45° to the Line of Fire, is:-.

Calibre.	Time of Flight. Seconds.	Yds. Wind Elevation.	Correction. Line.
60.Pdr. (8.CRH).	24.6	438	218
6"How. (Chg.5).	37.8	685	239

/Furthermore, the....

Furthermore, the effective value of the Wind Velocity for a 37.8 second Time of Flight is usually at least double that for a 24.6 second Time of Flight. In addition, "Meteor Reports" for long Times of Flights are less reliable than for short [times of flight].

These points always favour the Gun as against the How. in Map Shooting.

The diagram attached to Appendix "D" shows graphically for the various Calibres the Probable Errors of :-.

1. A Round from the M.P.I.

2. The displacement of the M.P.I.from the Target in Map Shooting.

3. A Round from the Target, in Map Shooting.

The targets considered in Appendix "D" are drawn to scale for comparison.

Andrew McNaughton [signed]

Lt.Col., C.F.A.,

C.B.S.O.,

R.A.,Canadian Corps.

17th.June 1918.

SYNOPSIS BY BATTERIES OF COUNTER BATTERY SHOOTS CARRIED OUT BY THE CANADIAN CORPS ARTILLERY FROM 26/12/17 to 4/5/18.

Btty.	Calibre.	Date. From.	Date. To.	No.of Shoots	Range.	Charge.	No.of Guns.	Average Correction to bring M.P.I. on to Target Elevation Mins.	Elevation Yds.	Deflection. Mins.	Deflection. Yds.	R.R.	R.R.O.	Time called to 1st "G"	Time 1st "G" to "V".
1.CHB.	60.Pdr.	7/4/18.	12/4/18.	3	10000	Full.	2	14	70	22	64	11	8	19	40
1.CSB.	9.2"H.	20/1/18.	23/4/18.	13	8182	4	2	67	214	43	102	32	29	19	58
2.CSB.	6"H.	26/12/17.	23/4/18.	42	8198	4	3	50	180	17	41	37	21	17	58
3.CSB.	6"H.	13/1/18.	21/4/18.	16	8318	4	3	58	209	32	77	28	19	21	55
4.CSB.	8"H.	6/1/18	21/4/18.	13	9573	4	3	49	108	57	159	34	25	16	64
5.CSB.	9.2"H.	9/1/18.	21/4/18.	22	8547	4	2	89	267	35	87	31	29	11	62
6.CSB.	6"H.	5/2/18.	24/2/18.	6	8983	4	3	58	164	46	120	23	14	12	79
7.CSB.	6"H.	18/2/18.	21/2/18.	3	8353	4	2	75	247	26	65	14	7	9	45
8.CSB.	8"H.	13/1/18.	23/4/18.	51	10304	5	2	77		44	132	26	24	14	66
9.CSB.	6"H.	24/1/18.	22/4/18.	38	7984	4	3	80	288	34	79	35	27	12	64
10.SB.	9.2"H.		23/4/18.	1	9450	4	2	5	10	2½	7	8	8	8	15
69.SB.	9.2"H.	21/4/18.	4/5/18.	5	11307	6	2	91	310	24	79	20	18	11	51
79.SB.	9.2"H.	1/4/18.	23/4/18.	2	9800	4	2	154	185	-	-	18	18	11½	56½
96.SB.	9.2"H.	26/2/18.	22/4/18.	2	9275	4	3	59	121	24	64	50	38	9	84
135.SB.	8"H.	2/4/18.	5/5/18.	8	11322	6	2½	50	-	16	53	23	23	14	59
140.SB.	6"H.	10/1/18.	15/3/18.	3	7970	4	3	109	399	44	102	23	17	20	56

Btty.	Calibre.	Date. From.	Date. To.	No.of Shoots	Range.	Charge.	No.of Guns.	Average Correction to bring M.P.I. on to Target. Elevation Mins.	Elevation Yds.	Deflection. Mins.	Deflection. Yds.	R.R.	R.R.O.	Time called to 1st "G"	Time 1st "G" to "V".
204.SB.	6"H.	1/4/18.	23/4/18.	6	8933	4	4	61	179	26	68	33	33	15	87
230.SB.	6"H.	1/4/18.	3/5/18.	3	8540	4	2	41	136	52	129	36	24	13	89
234.SB.	8"H.	21/4/18.	21/4/18.	2	9200	4	2	79	205	19	51	20	22	17	45
280.SB.	6"H.	26/3/18.	3/5/18.	5	8668	4	3	114	365	77	104	39	32	14	63
284.SB.	6"H.	1/4/18.	3/5/18.	8	8226	4	4	96	346	35	84	38	18	13	89
288.SB.	6"H.	12/4/18.		1	9325	4	2	20	43	15	42	21	15	-	55
321.SB.	6"H.	12/4/18.	3/5/18.	4	8400	4	2	27	92	32	78	41	34	13	59
326.SB.	6"H.	10/1/18.	13/3/18.	11	8523	4	2	101	338	81	99	27	18	18	71
337.SB.	6"H.	6/1/18.	23/4/18.	20	8270	4	3	59	212	55	129	41	33	12	62
450.SB.	6"Mk.19		13/1/18.	1	9723	Full.	2	20	156	50	143	25	14	22	-
48.Bty. C.F.A.	4.5"H.	3/1/18.	22/3/18.	7	5669	Full.	5	72 (False Yds)	90	9	15	34	16	16	151
36.Bty. C.F.A.	4.5"H.	9/1/18.	22/1/18.	5	5565	Full.	3	65	81	26	42	*	*	6	20
21.Bty. C.F.A.	4.5"H.	25/1/18.	26/3/18.	7	5918	Full.	4	134	168	27	46	37	19	11	75
58.Bty. C.F.A.	4.5"H.	3/1/18.	19/1/18.	8	5545	Full.	4	91	114	14	23	39	7	18	78

* Battery did not range according to methods laid down but fired salvoes & corrected on observations sent down by Airman. No estimate can be made of ranging rounds from data in hand.

R.R. – Ranging Rounds Fired. R.R.O. – Ranging Rounds Observed.

SYNOPSIS BY CALIBRES OF SHOOTS SHOWN IN APPENDIX "A".

Calibre.	No.of Shoots	Range.	No.of Guns.	Charge.	Average Correction to bring M.P.I.on to Target. Elevation. Yards.	Deflection. Yards.	R.R.	R.R.O.	Time called to 1st."G"	Time 1st."G" to "V"
60.Pr.	3	10000	2	Full.	70	64	11	8	19	40
4.5"H.	27	5680	4	5	115	30	37	14	13	85
6"H.	166	8300	3	4	241	89	34	24	15	64
8"H.	15	9525	3	4	125	144	32	25	16	61
8"H.Mk. 7	59	10450	2	5	210	121	25½	24	14	65
9.2"H.	40	8550	2	4	244	87	30	28½	13½	60
9.2"H.Mk.2	5	11300	2	6	310	72	20	18	11	61
6"G.Mk.19	1	9725	2	Full.	156	141	26	14	22	--

NOTE. The number of shoots by 60.Pdrs.in the period is only 3 but the results given are consistent with previous experience.

For the 6"Gun Mk.XIX the number of shoots is insufficient to give data to form a reliable conclusion and little previous experience has been had with this Piece.

Counter Battery Office.

C.B.636/20.Appendix C.

SUMMARY OF A.S.F.[352] CALLS.

Re-ranging in C.B.Shoots shown in Appendix "A".

Btty.	Date. 1918.	Calibre.	Gun No.	Range.	Charge.	Chg.in Elev.	Line Corr.	R.R.	R.R.O.	Time A.S.F. to "V".
1.CSB.	6/4	9.2"H.	1	8400	4	-1°20'	-	12	8	16
			3	8400		-	15'R.			
	12/4.	"	5	8250	4	-15'	5'R.	10	8	22
			6	8250		5'Up.	-			
			5	8250	4	-25'.	30'R.	16	16	24
			6	8250		5'Up.	40'R.			
2.CSB.	2/4.	6"H.	1	6360	3	20'Up.	-	10	10	15
			2	6360		-	-			
			3	6360		-	-			
			4	6360		-	-			
3.CSB.	17/2.	6"H.	3	880	4	1°25'Up.	30'L.	18	11	62
4.CSB.	12/4.	8"H.	2	8980	4	10'Up.	10'R.	10	9	10
			4	8710		30'Up.	10'R.			
			5	8710		10'Up.	-			
			6	8710		-	-			
	20/4	"	3	9200	4	5'Up.	20'R.	23	15	24
			4	9200		5'Up.	15'R.			
			5	9200		30'Up.	35'R.			
			6	9200		35'Up.	5'R.			
5.CSB.	31/3.	9.2"H.	1	8200	4	-30'.	5'R.	9	6	18
	2/4.	"	1	6975	3	-35'.	10'R.	10	9	12
8.CSB.	8/3.	8"H.	1	9763	4	-10'.	5'L.	14	10	23
			2	9763		-	30'L.			
	15/3.	"	1	10820	5	15'Up.	5'L.	11	11	22
			2	10620		50'Up.	-			
	18/3.	"	1	9671.	4	1°10'Up.	-	18	13	21
			2	9671.		1°10'Up.	-			
9.CSB.	21/3.	6"H.	1	7650	4	15'Up.	-	20	17	22
			2	7932		-15'.	25'R.			
			4	8042		-	15'R.			
	1/4.	"	1	7500	4	25'Up.	25'R.	16	15	17
			2	7870		-25'.	20'R.			
			3	8150		50'.	-			
	21/4.	"	1	8400	4	30'Up.	-	34	24	58
			3	8400		-30'.	20'R.			
69.SB.	21/4.	9.2"H.	1	12600	6	-20'.	10'R.	9	7	10
			2	12600		-	-			

(continued page 2.).

[352] Sent when battery is firing for effect and observer wishes to range the guns afresh.

Btty.	Date 1918.	Calibre.	Gun No.	Range.	Charge.	Chg.in Elev.	Line Corr.	R.R.	R.R.O.	Time A.S.F. to "V".
79.SB.	23/4.	9.2"H.	1	9900	4	2°Up.	-	16	14	44
			4	9900		-	-			
230SB.	3/5.	6"H.	1	8620	4	1°10'Up.	-	16	12	25
			2	8620		-	-			
280SB.	16/3.	6"H.	1	8280	4	-40'.	60'R.	21	18	36
			2	8280		-	-			
			3	8280		-	-			
337SB.	16/3.	6"H.	1	7985	4	-15'.	5'R.	63	50	82
			2	7985		-25'.	20'R.			
			3	7375		-45'.	70'L.			
			4	7375		-	-			
	17/3.	"	1	8720	4	-55'.	-	30	30	41
			2	8720		-10'.	-			
			3	8160		-20'.	-			
			4	8160		-35'.	-			

SYNOPSIS BY CALIBRES OF RE-RANGING IN C.B.SHOOTS.

Calibre.	No.of A.S.F.	Range.	Charge.	No.of Guns.	Correction to bring M.P.I. back to Target. Elevation. Yards.	Line Yds.	R.R.	R.R.O.	Time A.S.F. to "V".
60.Pdr.									
4.5"H.									
6"H.	9	7900	4	3	72	25	25	21	40
8"H.	2	9000	4	4	39	31	16	12	17
8".VII	3	10100	4	2	58	21	14	11	22
9.2"H.	6	8500	4	2	96	25	12	9	23
9.2".II	1	12600	6	2	40	37	9	7	10
6"G.									

Accuracy of Fire based on Appendix "B" and Range Tables of the various Calibres.

Calibre.	Range.	Charge.	PROBABLE ERROR YARDS.						EXPECTATION HITS PER 100						Relative % efficiency of Map versus Observed Shoots.		
			Rd.from MPI.		MPI from Target.		Rd from Target.		Map Shoot.			Observed Shoot.					
			Elev.	Line.	Elev.	Line.	Elev.	Line.	TARGET.			TARGET.			TARGET.		
									A.	B.	C.	A.	B.	C.	A.	B.	C.
60.	10000	Full.	44	8	56	51	71	52	1.0	1.0	.22	9.9	5.8	2.0	10	17.2	11
4.5".	5680	5	27	9	92	24	96	26	1.5	1.2	.26	13.6	9.4	3.0	11	12.8	8.6
6".	8300	4	25	6	192	71	193	72	.3	.3	.06	21.3	11	4.7	1.4	2.7	1.3
8".	9525	4	25	14	100	125	103	126	.3	.3	.05	9.5	8.5	2.1	3.1	3.5	2.4
8"Mk.7	10450	5	24	8	167	97	169	98	.2	.2	.04	17.2	11.1	3.8	1.2	1.8	1.1
9.2".	8550	4	41	11	195	69	197	70	.3	.3	.06	7.7	5.7	1.6	3.9	5.3	3.7
9.2"Mk.2	10300	5	15	4	247	57	247	58	.3	.2	.05	44.4	17.5	10.5	.7	1.1	.5
6"Mk.19	9725	Full.	39	5	124	112	130	113	.2	.2	.04	16.8	7	3.5	1.2	2.9	1.1

Probable Error of a Round from M.P.I. = ½ 50% Zone given in Range Tables.

Probable Error of M.P.I. from Target = $\frac{\sqrt{2}}{\sqrt{\pi}}$ Mean Error given in Appendix "B".

Probable Error of a Round from Target = $\sqrt{Sum\ of\ the\ Squares\ of\ Probable\ Error\ of\ Gun\ and\ of\ M.P.I.}$

Target "A" 50 yds x 10 yds parallel to the Line of Fire representing a Hostile Battery in ENFILADE.

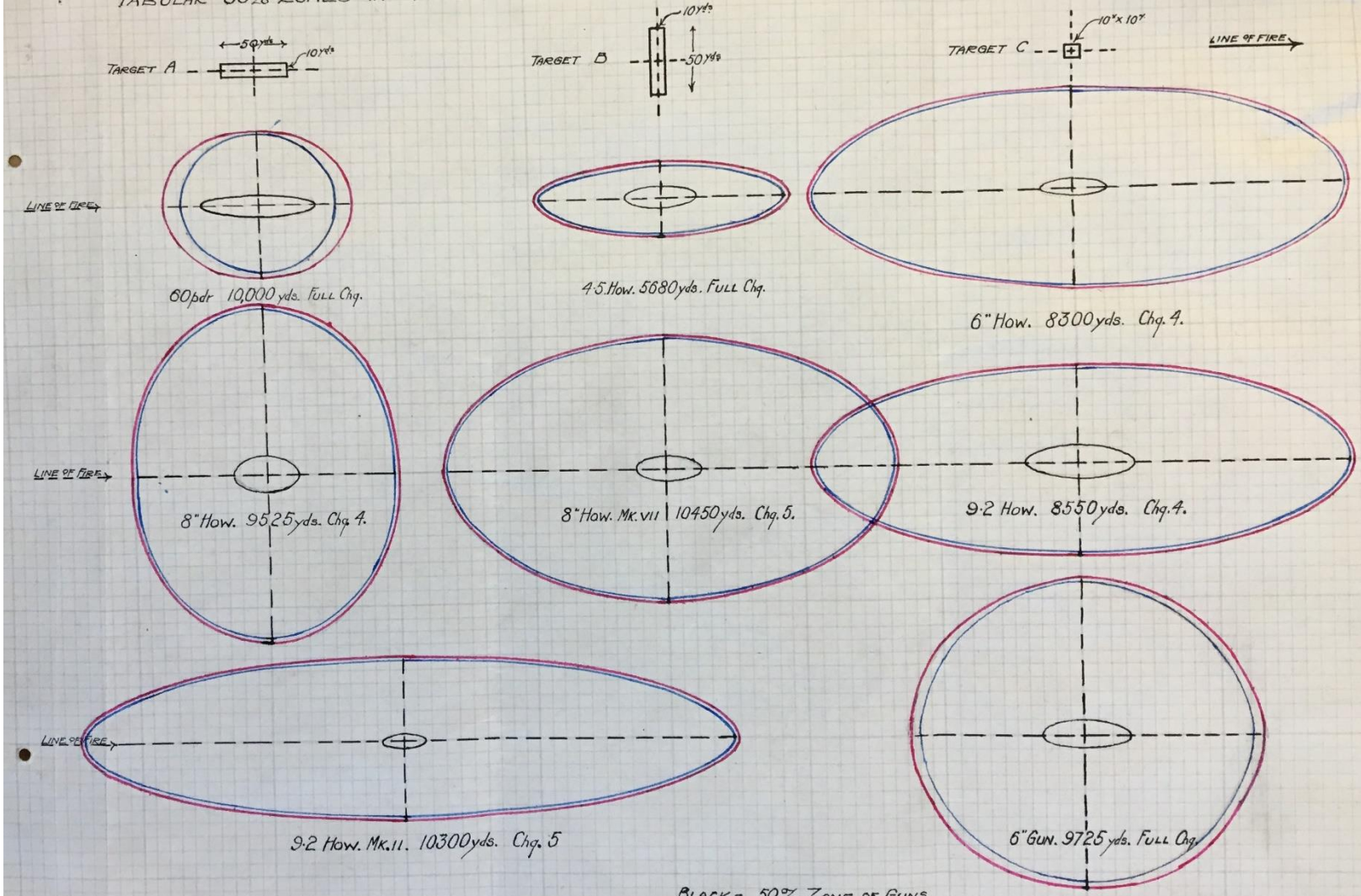
Target "B" 50 yds x 10 yds perpendicular to the Line of Fire representing a Battery under FRONTAL Fire.

Target "C" 10 yds x 10 yds representing a Dugout, Trench Junction or Cable Centre.

COMPARISON OF 50% ZONES

BASED ON

TABULAR 50% ZONES IN RANGE TABLES AND RESULTS OF AEROPLANE SHOOTS CANADIAN CORPS.



BLACK = 50% ZONE OF GUNS.
BLUE = 50% ZONE OF M.P.I. IN MAP SHOOTING.
RED. = 50% ZONE OF AN INDIVIDUAL ROUND.

SCALE 100 yds. = 1 INCH.

Appendix B

C.A.,Cdn.Corps No. 11/58.

SECRET

Report on the Use of Gas Shells by Canadian Corps

- VIMY RIDGE, 9 – 11 April 1917.

General.

1. Although the original prepared programme could not be carried out because of the weather conditions – yet the preparations for it form the body of this report – since a good deal of useful information was gained thereby. The remainder of the report is concerned with later bombardments with gas shell actually carried out.

2. The subject will be dealt with under the following headings and appendices attached as shown :-

		Appendices.
A. Chemical Viewpoint.		
B. Allotment of Gas Shells	- Analysis of Shells used	– App.I.
C. Choice of targets.	- Map showing targets	- App.II.
D. Aim of Bombardment		
E. Registration.	- Orders re Registration.	- App.III.
F. Arrangement of Bombardment	- Operation Orders.	- App.IV.
G. Duplication of Programme.		
H. Instructions to Batteries.	- Copy of that issued.	- App.V.
I. Wind Weather Arrangements.	- Table of Times.	- App.VI.
J. Actual Weather Conditions.		
K. Conditions succeeding Zero.		
L. Bombardment of Vimy Village.	- Particulars.	- App.VII.
M. Recommendations.		

A. Chemical Viewpoint.

The G.O.C.R.A., First Army, advised by the Chemical Advisor, First Army, issued to Canadian Corps Artillery Staff "Notes on the Use of Gas Shells" which formed the basis of decisions in different matters regarding the employment of these shells. It became necessary to emphasise certain points and to impress them upon the Artillery Officer in control. The points were these, quoting from the document mentioned above, which is too long to be included in this report.

(i) "P.S. is lethal as well as lachrymatory but is to be used as lachrymatory".
(ii) "If the wind is more than seven miles per hour no bombardment of gas shells should take place".
(iii) "In certain cases in which H.E.shell is not efficacious, poison shell can be employed with very good results".
(iv) "Nothing is gained by increasing unduly the rate of fire for it is useless to attempt to form, with these shells, a cloud which will produce toxic effects at a great distance".
(v) "Poison shells should not be employed for barrage fire except under very exceptional circumstances".

These considerations materially affected the preparation of the programme, and the advice given to Artillery Staff in connection with it.

B. Allotment of Gas Shells.

The following allotment was made the Canadian Corps for its use :-

BSK	6000	DSK	2500
BCBR	7000	DPS	3000
BJBR	4000	DCBR	9000
	17000		14500

It is a matter for consideration later, when more experience has been gained and data collected, what proportion of the different shells, and particularly the proportion of lachrymatory to lethal, would be the most suitable allotment for average requirements.

Arrangements for the first bombardments will not likely be effected by the numbers of each shell allotted, but more likely by the number of guns available and the time for which each is available.

The preparation of the last bombardments, however,must also be influenced, and conceivably adversely, by the numbers and characteristics of the shells remaining. It might be found however that considerations affecting supply might make matters so complicated that it would be impracticable to allot shells in any proportions that may be decided upon as advisable.

Attached (Appendix I) is an analysis of the numbers of the different type of shell planned for use in the bombardments under consideration.

C. Choice of Targets.

Two considerations influenced the choice of objectives, one the idea of choosing a target upon which H.E. would not be so effective as Gas Shells, and, the other that, it should be as stationary as possible so that personnel, to remain effective, must remain in the place bombarded.

It was decided to limit the use of Gas shells to counter-battery work, and to use it for other objectives only under very special circumstances.

The Counter Battery Staff Officer (C.B.S.O.) under Corps Artillery, then became responsible for the use of Gas Shells. Under his control he had all 60-pdr Batteries and a certain number of 4.5" Howitzer Batteries which had been allotted to him.

In consultation with Chemical Advisor, Canadian Corps, the C.B.S.O. decided upon the targets as shown on attached map (Appendix II). The choice was based upon careful consideration of the location and previous history of each battery. Practically all of these batteries had been bombarded on various occasions with H.E. of heavy calibre and were still in action. Some characteristics of location may be pointed out:-

S 12 – In edge of wood – on side of hill.

S 13 – S 14 – S 16. This group in a valley and close together. The path between them was greatly used by enemy as overland route forward.

T 10 – T 11. Batteries in woods and near roads used by enemy. Had given us great trouble and H.E. had small effect.

T 15. Battery dug into the side of a railway cutting.

T 14. In edge of wood on sloping hill.

T 63 – T 57. In cellars in Vimy village and beside used roads.

B.17 – B 18 – B 19. All on the edge of FARBUS WOOD. These guns were within the infantry objective and it was hoped that their possible capture would give us valuable information as to the result of the gas shell bombardment. (These batteries were subsequently captured, but gas shell had not been used because of wind conditions).

D. Aim of Bombardment.

It was ordered that no gas shells were to be used before zero, (except for Registration). Our aim was then, commencing at zero, to neutralise the enemy batteries chosen, as soon as possible. Neutralisation to prevent an enemy barrage on our attacking troops was the most important consideration. This would be partially obtained by merely making his artillery personnel wear their respirators. Bombardments were arranged to surprise the enemy at first with a quick burst of fire, and the prolonged with a view to exhausting his box. See Section"F" below.

E. Registration.

Careful orders in regard to registration were issued. It was decided that registration would take place on easily observed points close to targets, and that these registrations could proved with a few rounds of gas shell. Then, after pooper calibration, batteries would be in a position to switch o the targets at zero.

Copy of orders issued for registration is attached, as well as those issued with regard to co-operation with Balloon Coys. (Appendix III) (A) and (B).

F. Arrangement of Bombardment.

1. Attached operation orders (Appendix IV) (a) and (B) show the arrangement of the gas shells bombardment.

2. The main considerations which influenced the arrangements were the number of guns available and the times during which they were available. As will be noticed, some guns were available throughout the bombardment, and some only at intervals, e.g.,

Table C 1. Targets B 17 – B 18 – B19.

Battery D/ 170 with 6 guns would use all guns from 0 – 5, 5 – 15 and 215 – 230 and only 3 guns from 15 – 215 and 230 – 310, the longest periods. At the same target Battery D/72 with 6 guns co-operated with all guns at 0 – 5, 5 – 15 and 215 – 230 minutes after zero. At other times this battery was available for other work.

3. One of the strongest advantages of the use of gas shells from an artilleryman's point of view, is that it sets free a number of guns, particularly at the latter part of the bombardment, for use for other purposes. This is not the case in a H.E. bombardment.

4. In arranging the fire for these bombardments as quick a burst as the maximum rate of fire would allow was ordered for the first five minutes, using lethal shells with the 4.5" Howitzer and P.S. with the 60pdr-Gun. From 5 – 215 S.K. was made use of to prolong the bombardment and in the case of the 4.5" Howitzers and addition was made of two or three bursts of lethal shell., during this time to catch any personnel changing respirators, or whose respirators had already become exhausted. Then from 215 – 230 minutes after zero all guns available fired an intense rate of lethal shell – for the same purpose -. Then slower fire was continued to complete the process of exhausting the German respirator and affecting the personnel.

5. The bombardments of these batteries which lay inside the infantry objective was ended at 310 minutes after zero. Since the infantry were not due to arrive for a minimum of 300 minutes after that time, there was quite sufficient time for the gas to clear, even in the woods. In the event of any of the batteries remaining in action after 310 minutes after zero, it was arranged to take them on with H.E. But it was considered that more than sufficient gas shells were to be used to put the battery out of action for the desired time afterwards.

6. Instructions based in the operation orders were issued to officers concerned to assure that the proper ratio of the different kind of gas shell were issued to each battery. Each battery was also instructed to draw the proper ratio.

G. Duplication of Programme.

Since the Gas Shell Bombardment depended altogether on the weather conditions, it was necessary to issue alternative orders in case the weather was unfavourable. Operation orders for the bombardments of the same targets with H.E. were therefore prepared and issued. Batteries concerned were instructed that they would be notified one half-hour before zero as to which programme would be in force. This notification was in the form of a code-word, the translation of which had been sent to the batteries, attached to the operation orders.

H. Instructions to Batteries.

It was considered essential that the officers actually controlling the fire of the batteries, should have instructions in certain matters connected with the use of Gas Shells. Accordingly, at the request of the C.B.S.O., the Chemical Advisor, Canadian Corps called on the O.C.Batteries concerned and discussed maters with them. Also at the request of the C.B.S.O. he issued the attached "Instructions for Firing Gas Shells" (Appendix V). These were made as short as possible and a copy attached to operation orders.

I. Wind and Weather Arrangements.

Since gas shells are not effective and ordered not to be fired with a wind over 7 m.p.h., the question arose as to upon whose shoulders the responsibility for the decision rested. The G.O.C.R.A, Canadian Corps placed the decision in the hands of the C.B.S.O. who was in actual charge of the arrangements. The latter, while keeping the responsibility asked the C.A., Cdn.Corps to decide whether the weather conditions were favourable, when it was needed.

Zero time had been placed as 5.30.a.m. Monday April 9th. Final decision had to be reached an hour before zero, to enable batteries concerned to be notified half-hour before zero. The C.A. made arrangements to telephone reports at 12 midnight, at 2.30.a.m. and the final decision at4.30.a.m. These reports were also despatched by orderly at the same time to ensure arrival.

The C.A. established a weather station with an anemometer and wind vane and arranged to have reports as to speed and direction of wind and general weather conditions every half hour. With these and the usual meteorological reports, a decision could be made.

In case the wind was favourable at zero and became unfavourable later before the bombardment was complete, it was useful to know how many shells at any time after zero had been fired on any target. This information would influence any decision as to the necessity for switching into H.E. at any time. The attached table (Appendix VI) was prepared for guidance in such an eventuality.

J. Actual Weather Conditions.

Zero as ordered as 5.30.a.m. April 9th, up until midnight before conditions were excellent, though the probabilities unfavorable, but towards zero the wind increased in speed until at 4.50a.m., which was the latest time possible for decision, it was blowing at 18.m.p.h., thus rending the employment of Gas shells useless. Accordingly, the bombardment with Gas shell was cancelled, and the orders regarding H.E. put into effect.

K. Conditions succeeding Zero.

The attack on the morning succeeded and our troops occupied the ridge. This compelled the enemy to withdraw those batteries which had been chosen as gas shell targets and some were captured. This procedure, of course, rendered useless the plans arranged.

At 5.p.m. on April 9th, our infantry had occupied a line opposite VIMY village and on the hill above it, as shown in blue on the map. Between then and dark our observes reported an enemy concentration beginning in VIMY village, which at dark was judged to have reached a strength of seven or eight thousand. This was evidence pointing to a counter attack during the night, especially as prisoners reported that orders had been issued to hold VIMY ridge at all costs. It was expected that the counter-attack if launched at all, would be directed against the valley (BOIS DE BOUVAL) in S 30 C.

L. Bombardment of VIMY village.

The C.B.S.O. and C.A. suggested to G.O.C.R.A, Cdn.Corps, the advisability of shelling VIMY village heavily with gas shells, in order to cause casualties amongst troops known to be there, to cause panic and lower morale and prevent any organised attempt at a counter-attack. The mater was referred to G.O.C. Canadian Corps and permission was obtained.

No attempt was made to bombard the area of VIMY village. It was arranged that fire should be directed against certain linear targets so that the wind would carry the gas over important sections. These sections were chosen as the main cross-roads post which troops would have to pass to reach the front desired. They are shown on the attached map and the attached table (Appendix VII) gives particulars as to the shooting. The wind during the night from 11.30.p.m. until 7.30.a.m. was favourable being under 7 m.p.h. and from the S.W., so that VIMY village was in the 1ce of VIMY ridge. While no direct evidence has as yet been obtainable as to the result of the shoot, yet it is generally held by all concerned that this bombardment effectually prevented the fulfillment of the enemy's plans for a counter-attack before our line had been consolidated.

M. Recommendations.

1. Experience has shown it to be necessary that the Corps Chemical Advisers have facilities for establishing a weather station from which they can obtain quick reports. For this purpose the authorisation of an anemometer and proper weather vane and an increase in personnel is advisable. It has been necessary to keep the station established here, continually working from zero day and night until this date (five days) and we are still liable to be asked to make a decision at any moment as to use of Gas Shells.

2. The issue of a pamphlet containing sound information on the use of gas shells, both from a Chemical and Artillery point of view, would be of great value. S.S.134 is of little use.

3. The issue of instructions to officers in control of the actual fire of the batteries had been found necessary and should be general.

(sd) W.ERIC HARRIS, Captain.

C.A., CANADIAN CORPS

APPENDICES FOLLOW.

SHELLS TO BE USED IN BOMBARDMENTS. (APPENDIX I).

Gun.	Battery.	Target.	P.S.	S.K.	C.B.R.	J.B.R.	Total Lachry-matory	Total Lethal.	Total.	Grand Total.	Remarks.
4.5″ How.	D.170 & D.72.	B.17		280	110	170	280	280	560		Average of 18 Bombard ments is 580 shells per bombardment.
		B.18.		280	110	170	280	280	560		
		B.19.		280	110	170	280	280	560		
	D.22 & D.43.	T.57		350	125	225	350	350	700		
		T.63.		350	125	225	350	350	700		
	D.36 & D.245.	S.12		430	140	195	430	335	765		
		S.13		430	140	195	430	335	765		
	D.503 & D.845.	S.14		380	110	170	380	280	660	5930	
		S.16		380	110	170	380	280	660		
60-pdr. Gun	1/1 Essex.	B.25	225.	175	100		400	100	500		P.S. taken as lachrymatory
		B.60	225	175	100		400	100	500		
	145	B.62	225	125	150		350	150	500		
	129	T.14	250	175	75		425	75	500		
		T.53	250	175	75		425	75	500		
	2 C.H.B.	T.10.	225	125	150		350	150	500		
	1 C.H.B.	T.11	225	125	150		350	150	500		
	152	T.15	225	125	150		350	150	500		
	142	T.54	225	175	100		400	100	500	4500	

10430

SECRET. COUNTER BATTERY OFFICE APPENDIX III.a.
CANADIAN CORPS ARTILLERY.

Distribution of Gas & Lachrymatory Shell. C.B 12/15.

4.5" HOWITZER BATTERIES

Battery.	D.A.	Location.	No.of Hows.	Arc of fire.	C.B. Group.	Probable Target in area.	Point to be Registered.	Dumps. at guns	Special
				(a)	Permanently	Detailed.			
D/170	1.C.D.A.	A.13.b.98.78.	6	50 - 110	50.H.A.G.	B.1.d B.2.c. B.8.a&c	B.2.C.43.00	2500	
D/43	3.C.D.A.	S.25.b.3.2.	6	55 - 110	76.H.A.G.	T.19.c&d. T.25.a,b&d	T.19.c.43.23	2500	
Not in Action.	Reserve D.A.	X.16.d.8.3.	6	60 - 120	26.H.A.G.	S.5.a&b, S.6.a & c	S.5.b.80.80	2500	
			(b)	Attached for period of intense neutralisation.					
D/72	1.C.D.A.	A.8.a.70.18	6	55 - 125	50.H.A.G.	B.1.d, B.2.c, B.8.a&c	B.2.c.45.00	800	
D/22	2.C.D.A.	A.8.a.43.45	6	60 - 110	50.H.A.G.	T.19.c&d, T.25.a,b&d	T.19.c.43.23	800	
D/245 D/76	Reserve D.A.	X.22.b.6.9	6	60 - 120	20.H.A.G.	S.5.a&b, S.6.a&c	S.5.b.80.80	900	
		4.	24.					10000	10000

60 Pdr. Batteries.

Battery.	Location.	No.of Guns.	Arc of Fire.	C.B. Group.	Probable Target in area.	Point to be registered	Dumps at guns.	Special
1/1 Essex.	F.24.a.1.5	6	20 - 90	50.H.A.G.	B8c&d, B14b&d, B15a&c	B.15.a.25.50	1000	
145	F.17.d.0.7	6	30 - 100	50.H.A.G.	B8c&d, B14b&d, B15a&c	B.15.a.25.40	1000	
121	F.4.a.4.3	6	60 - 110	76.H.A.G.				
31	X.27.b.3.0	6	50 - 115	76.H.A.G.				
129	F.5.d.7.9	6	30 - 110	76.H.A.G.	T7d, T8c, T7b,		1000	
142	F.1[illegible].a.2.8	3	40 - 110	76.H.A.G.	T7d, T8c, T7b,	T.13.b.63.80	500	
	[illegible].2.d.5.3.	3	40 - 110	76.H.A.G.				
2 C.H.B.	X.1[illegible].c.5.2	4	45 - 115	2 C.H.G.	M36d, N31c, Sb6, T1a	N.31.c.87.47	500	
1 C.H.B.	F.4.d.7.6	4	35 - 120	2 C.H.G.	M36d, N31c, Sb6, T1a	N.31.c.87.47	500	
152	F.5.b.8.7	6	45 - 115	2 C.H.G.	M36d, N31c, Sb6, T1a	N.31.c.87.47	500	
		50					5000	3500

Gun dumps to be completed by z - 1.
Registration on points shown using Gas Shells to be completed by Z - 1. Observation by .Balloon Coy.
For details see C.B. 12/16 attached.

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30 - 3 - 17. C.B.S.O., Canadian Corps R.A.

SECRET. COUNTER BATTERY OFFICE APPENDIX III. b,
CANADIAN CORPS ARTILLERY.

C.B 12/16.

The following Registration will be carried out with Balloon Observation: -

NO.	BATTERY.	LOCATION.	GROUP.	POINTS. A.	B.	C.	BALLOON. COY.	REMARKS.
1	D/174	A.13.b.98.78	50.H.A.G.	B.2.c.43.00.			1st	
2	D/43	S.25b3.3	76.H.A.G.	T19c43.23			1st	
3		X.16.d.8.3	2 C.H.A.G.	S5b80.80			2nd.	D.
4		A.8.a.70.18	50.H.A.G.	B2c43.00			1st	D.
5	D/22	A.8.a.43.45	50.H.A.G.	T19c43.23			1st	D
6	D/76	X.22.b.6.9	2 C.H.A.G.	S5b80.80			2nd	D
7	1/1 Essex	F.24.a.1-5	50.H.A.G.	B15a25.40	B2b10.00	T26a20.05	1st	
8	145	F.17.d.8.7	50.H.A.G.	B15a25.40	B8b50.80	T26a20.05	1st	D
9	121	F.4.A.4.3.	76.H.A.G.		T1a65.80	B8a30.95	1st	
10	31	X.27.B.3.8	76.H.A.G.		S18c90.35	B1d90.55	1st	
11	129	F.5.d.7.9	76.H.A.G.		T13d50.45		1st	D
12	142	F.11.a.2.8	76.H.A.G.	T13b63.80	T20c10.55		1st	D
13	142	A.2.d.5.3	76.H.A.G.		T20c10.55	T2c95.45	2nd	D. Not to fire before Z-1
14	2 C.H.B.	X.15.c.5.2	2 C.H.A.G.	N31c87.47	M35a60.20	S11c20.80	2nd	
15	1 C.H.B.	F.4.d.7.[illegible]	2 C.H.A.G.	N31c87.47	S18c90.20	B7b53.30	2nd	
16	152	F.5.b.8.7.	2 C.H.A.G.	N31c87.47	T13b65.80		2nd	D. Not to fire before Z-2

In connection with the programme for neutralisation of H.B's, the registration of the points given in Column A will be verified with a few rounds of Gas Shell.

Batteries marked D are to be registered under cover of other shooting as necessary under arrangements of Group Commander concerned.

(sd) L.P.NAPIER. Lieut.
for Lt-Col., C.F.A.,
C.B.S.O.,
Canadian Corps R.A.

30 - 3 - 17

SECRET. COUNTER BATTERY OFFICE APPENDIX IV.a.

TABLE C.1. CANADIAN CORPS R.A. COPY NO.C.A.CDN.CORPS.

Neutralisation by Gas Shell 4.5" Hows. ORDER NO.18.

Group.	Battery.	No.of Guns.	Targets. Type of Gas.	Rounds to be fired in each period. 0-5 CBR	5-15 SK	15-215 (a)	215-230 JBR	230-310 JBR	310-510 BSK	Total. (b)	Guns available for other C.B.work. 15-215	230-310	310-510	Remarks.
1.C.B.G.	D/170	6	B.17 B18 B.19	90	120	3 SK 600 CBR 150	180	3 150	--	1290	3	3	--	To 310 only
1.C.B.G.	D/72	6	B.17 B18 B.19	90	120	-	180	-	-	390	-	-	-	2 periods only
1.C.B.G.	D/22	6	T.57 T63	90	120	-	180	-	-	390	-	-	4	2 periods only
2.C.B.G.	D/43	4	T.57 T63	60	80	SK 500 CBR 100	120	150	-	1010	-	-	4	
3.C.B.G.	D/36	6	S.12 S13	90	120	4 SK 600 CBR 160	180	4 150	4 100	1400	2	2	2	
3.C.B.G.	D/503	4	S.14 S16	60	80	SK 500 CBR 100	120	100	2 100	1060	-	-	2	
3.C.B.G.	D/245	6	S.12 (I) S.13 (1) 2.14 (2) S.16 (2)	90	120	-	180	-	-	390 5950 for 9 Batteries	-	-	-	2 periods only

(a) In period 15-215 CBR is to be fired in 3 bursts at irregular intervals at "Intense" Rate from all guns.

(b) If the particular type called for is not available, shell with nearest chemical properties will be substituted.

SECRET. COUNTER BATTERY OFFICE APPENDIX IV. b.

TABLE C.2. CANADIAN CORPS R.A. COPY NO. C.A.CDN.CORPS.

Neutralisation by Gas Shell 60 Pdrs.

Group.	Battery.	No.of Guns.		Rds. to be fired in each period.							Guns available for other C.B.work.		
			Targets.	0-15	15-215(a)	215-230	230-310(a)	310-495(a)	495-510	Total.	15-215	230-310	310-
			Type of Gas.	F.S.	P.S.or SK.	CBR.	PS or SK.	PS or SK.	CBR.	(b)			
1.C.B.G.	1/1 Essex.	6	B25,B60	100	2 300	100	2 200	2 100	100	1000	4	4	4
1.C.B.G.	145	4	B.62	75	2 150	75	2 50	2 75	75	500	2	2	2
2.C.B.G.	129	5	T14,T53	75	2 300	75	3 200	2 275	75	1000	3	2	3
2.C.B.G.	142 (½)	3	T.54	50	2 150	50	2 100	2 150	50	500	1	1	1
3.C.B.G.	2 C.H.B.	4	T.10	75	2 150	75	2 50	2 75	75	500	2	2	2
3.C.B.G.	1.C.H.B	3	T.11	75	2 150	75	2 50	2 75	75	500	1	1	1
3.C.B.G.	152	6	T.15	100	2 150	50	1 50	1 50	100	500	4	5	5

(a) In these periods the fire will be maintained with a portion only of the guns.

(b) If the particular type called for is not available, shell with nearest chemical properties will be substituted.

Correction. Fire on Targets B.25, B.60, B.62 will be completed at 440.

April 6th, 1917. APPENDIX V.

INSTRUCTIONS FOR FIRING GAS SHELLS

GENERAL.

1. Gas Shells will not be fired when the wind is over 7 miles per hour. The decision taken in this regard will be wired to batteries concerned at half hour before Zero.

2. Ranging with Gas Shells must not be caried out on the target itself. Ranging can be done on a reference point in the area – and after calibration the fire switched to the target.

3. Except in the first five minutes, to effect surprise, rapidity of fire is not advantageous.

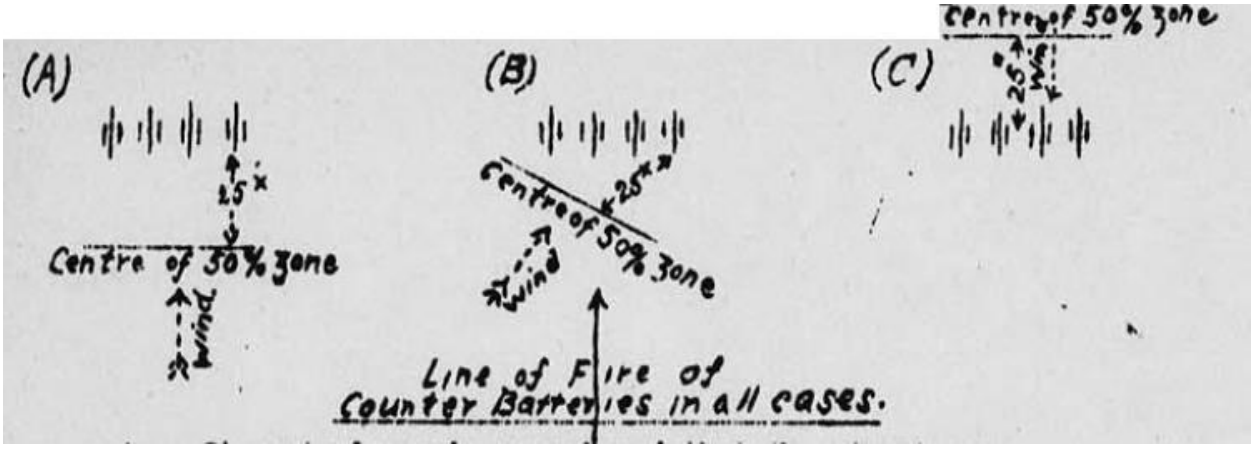
4. Each gun should not be required to cover more then 25 yards of front.

CONTROL OF FIRE.

1. To produce efficient results with gas shells the bursts must take place close to the target but on the wind ward side of it.

2. With the 4.5" How. and 60-pdr.gun, fire must be so controlled that the centre of the 50 percent zone lies [*sic*] about 25 yards to windward of the target.

3. The direction of the wind thus becomes an essential factor. The diagram below illustrates this:-



4. It must always be remembered that the utmost care and accuracy is necessary to obtain the full efficiency of a Gas Shell bombardment.

(sd) W.ERIC HARRIS, Captain.

C.A., Cdn.Corps.

for C.B.S.O., Cdn.Corps Artillery.

NUMBER SHELLS FIRED BY CERTAIN TIMES AFTER ZERO.

APPENDIX VI.

A.- LACHRYMATORY.

B.-LETHAL.

C.-TOTAL.

TARGET. (on each).	Shells.			Fired by 65.mns. (6.35.a.m.)			Fired by 150 mns. (8.00.a.m.)			Fired by 230 mns. (9.20.a.m.)			Fired by 310 mns. (10.40.a.m.)			Fired by 510 mns. (2.00 p.m.)		
	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.
B.17. B18. B.19	280	280	560	130	72	202	215	93	308	280	230	510	280	280	560	Ended.		
T.57.T63.	350	350	700	163	87	250	269	108	377	350	275	625	350	350	700	Ended.		
S12.S13.	430	335	765	155	80	235	283	114	397	380	260	640	380	335	715	430	335	765
S.14.S16.	[illegible]	280	660	142	73	215	248	94	342	330	230	560	330	280	610	380	280	66
B25.B60.	400	100	500	87	-	87	150	-	150	200	50	250	300	50	350	400	100	500
B62.T10 T11.	350	150	500	113	-	113	177	-	177	225	75	300	275	75	350	350	150	500
T14.T53.	425	75	500	75	-	75	140	-	140	187	38	225	287	38	325	425	75	500
T.54	400	100	500	87	-	87	150	-	150	200	50	250	300	50	350	400	100	500
T.15.	350	150	500	138	-	138	200	-	200	250	50	300	300	50	350	350	150	500

NOTE. With 60-Pdr. – P.S.shell is included in lachrymatory – but adds to lethal effect.

BOMBARDMENT VIMY VILLAGE.

APPENDIX. VII.

Date.	TG.E.	Guns.	Target - Linear		Number Shells.				REMARKS.
			Between	and	S.X.	P.S.	C.B.R. J.B.R.	TOTAL.	
Night. 9-10 April. 1917.	12.00 to 12.30.	25-60 Pdr.	S24d.9.6.	T19.C.21		750		750	
	12.30. to 1.00.	25 60 Pdr.	T19d 9.7	T20C33		750		750	
	12.00 to 12.30.	14 4.5”How.	S18C 74	S18C 90			1260	1260	
	12.00 to 12.30.	14.4.5”How. Repeated between – 3.00 a.m. – 4.00.a.m. - 6.00.a.m. – 7.00 a.m.	T19C 96	T19d 32			1260	1260 4020 4020 4020 12060	
		Because of lack of supply at certain batteries, total fired was about 10,000. Wind was S.W. changing from 1.8 to 6.7 m.p.h.							

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RG9-III-D Canadian Corps War Diaries and Canadian War Records Office Files

RG24 Department of National Defence Files

RG150 Service Files

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